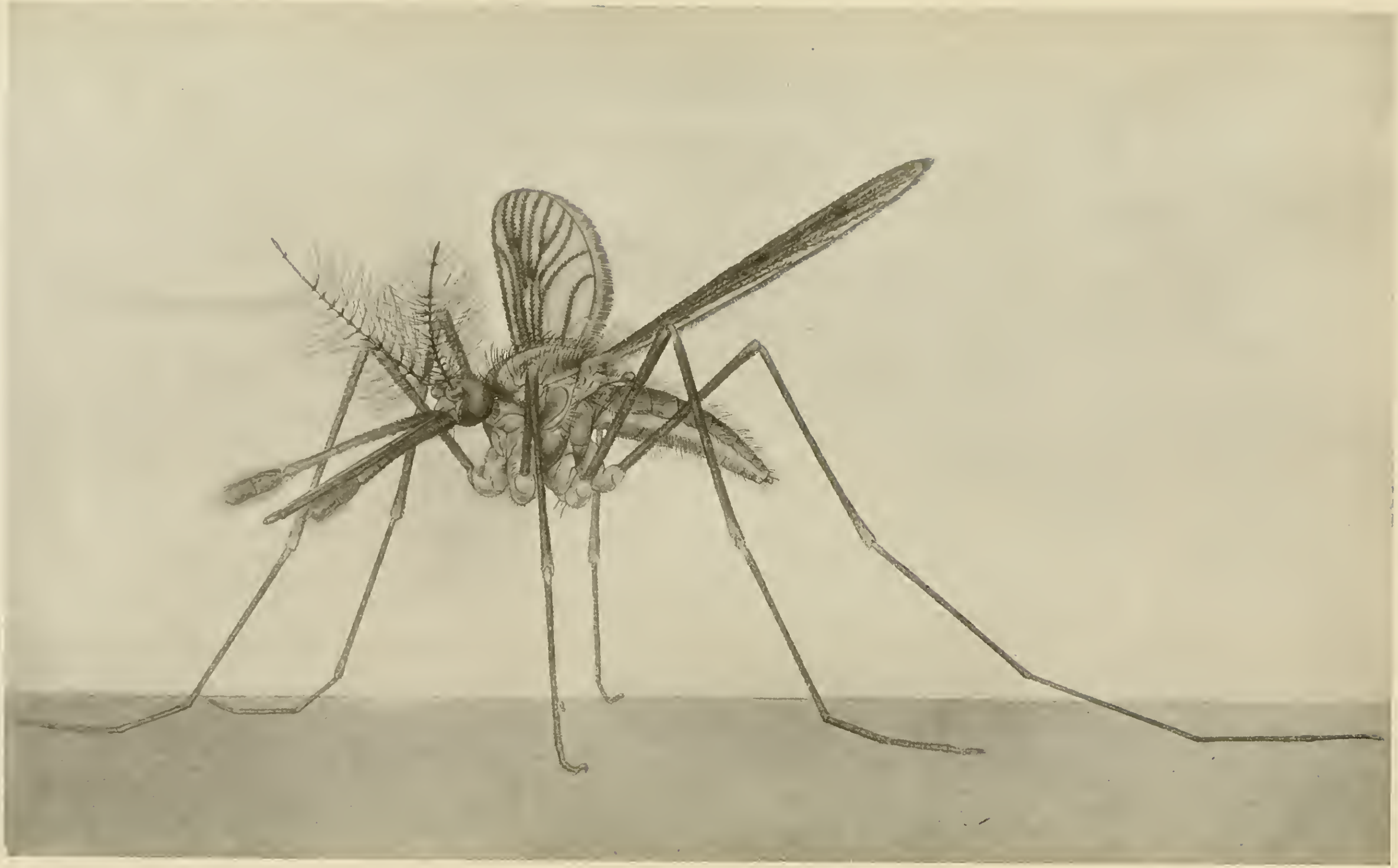
AMERICAN MUSEUM OF NATURAL HISTORY

# INSECTS AND DISEASE

BY
C.-E. A. WINSLOW
AND
FRANK E. LUTZ

GUIDE LEAFLET No. 48



MODEL OF MALARIAL MOSQUITO

# INSECTS AND DISEASE

A Statement of the More Important
Facts with Special Reference to
Everyday Experience


BY

C.-E. A. WINSLOW AND FRANK E. LUTZ



American Museum of Natural History

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"I deal with certain little Invertebrata; animals which work in darkness and in stealth, little animals which in times of Peace we politely ignore, yet little animals which in times of War may make or unmake an army corps. As that wise old Greek, Aristotle, wrote—and he knew quite a lot about them—'One should not be childishly contemptuous of the study of the most insignificant animal. For there is something marvellous in all natural objects.'"

*A. E. Shipley, "Minor Horrors of War."*

# INSECTS AND DISEASE

By C.-E. A. Winslow
and F. E. Lutz

## THE IMPORTANCE OF INSECTS

The life of man is affected, for good or ill, at a thousand points by the activities of the humbler members of the living world of which he forms a part. The lower animals and plants supply us with our food and clothing and with materials for providing shelter against the elements. On the other hand, certain species are our relentless foes, waging constant war against our property and even our lives.

In the case of the insects, for example, as we review the multitudes of these creatures within our limited horizon, we not only admire the wondrous beauty of this species or the amazing instincts of that; we are awestruck at the financial havoc wrought by one and appreciate with gratitude the way in which another helps to restore the balance of Nature and protect us from starvation. Even among the microbic forms of life, in the world of the "infinitely little," we find, on the one hand, the bacteria of the soil fixing the nitrogen of the air and making it available for our growing crops — on the other, the bacilli of tuberculosis and of a score of other deadly diseases, threatening the health and life of hundreds of thousands.

One of the most interesting and important chapters in the story of the interrelationships between mankind and the lower forms of life is that which deals with the triple relation between the microbe, the insect and the human being in the spread of certain communicable diseases. The types of insects and their relatives concerned are, on the whole, more disgusting than beautiful; their habits are not attractive, nor are their instincts extraordinary; but they have profoundly influenced the history of the human race. You and I may lose our lives by reason of their activities; we certainly can aid in combating them. It, therefore, behooves us to become well acquainted with our foes.

## CHARACTERISTICS OF INSECTS

First of all, a word should be said as to the characteristics of these creatures and their place in Nature. Those animals which have no internal skeleton but do have, at some period of their lives, jointed legs are called Arthropods. Familiar examples are lobsters, spiders, centipedes, and insects. We are now chiefly concerned with certain insects but we must also consider mites and ticks, creatures which are more closely related to the spiders. An insect has its body divided into three regions: head, thorax, and abdomen. Its jointed legs are borne by the thorax, the segments of the body which are just back of, but separated from, the head; there are never more than three pairs of such legs in an adult insect. Spiders, mites, and ticks have, typically, four pairs of jointed legs, and the head is merged with that part of the body which bears the legs.

The great majority of insects are winged, when adult, and most winged insects have two pairs of wings, but the members of the large Order Diptera, to which mosquitoes and flies belong, have never more than one pair. Nearly all of the strictly parasitic insects are wingless, even when adult. We will take up first those disease-bearing insects which have, when adult, one pair of wings, next certain wingless insects, and finally the mites and ticks.

Two sorts of Diptera or two-winged insects are of interest in the present connection: (1) ordinary "flies" with three-jointed antennæ; and (2) mosquitoes, gnats, etc., which have eight or more freely moving joints in each antenna. The Muscidæ and the Tabanidæ (p. 13) are of the first sort.

The Muscidæ, a group which includes our commonest disease-bearing insect, the filth fly, are characterized as follows:

The squamæ (see Fig. 1) of Diptera are scale-like structures placed back of the roots of the wings and above the knobbed "balancers"; and the Muscidæ agree with the related Diptera in having these squamæ large. The auxiliary vein in the wing (see Fig. 1) is distinct in its whole course, and the first longitudinal vein is never very short. The thorax has a complete transverse suture. The eyes of the male are usually much nearer together than those of the female; sometimes, in fact, so close that they touch each other.

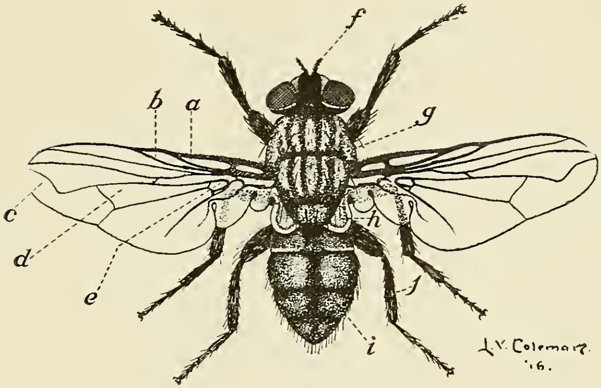


Fig. 1. THE FILTH FLY (*Musca domestica*)

a. Auxiliary vein
b. First longitudinal vein
c. Fourth longitudinal vein
d. Discal cell
e. Anal cell
f. Antennæ
g. Transverse suture
h. Squama
i. Abdomen
j. Tibia

## THE FILTH FLY

*Musca domestica*

More volumes have been written about this insect in the last twenty years than have been devoted to any other one insect (unless it be the honey-bee) since man became civilized enough to write about insects at all.

This fly is commonly called the "house fly," but that name has been justly criticized because it seems to imply a necessary domestic relation. We do not believe that this insect should be a *house* fly in the future; and Dr. L. O. Howard of Washington, in view of its relation to disease, has suggested that is should be called the Typhoid Fly. This seems, on the other hand, to relate rather too closely a disease and an insect which are sometimes, but not universally, connected. Filth Fly is perhaps the best term and one that is undoubtedly applicable. The fly breeds in filth, it resorts to filth, and it carries filth with it everywhere it goes.

The excellent figures given here, combined with common experience, are sufficient for the identification of the "ordinary house fly," or "typhoid fly," or "filth fly." Note (Figs. 1 and 4) especially the rounded angle in the fourth longitudinal vein, the plumose antennal bristle, the absence of stout bristles on the abdomen, the absence of a vertical row of bristles between the base of the hind legs and the "balancers," and the absence of a prominent bristle near the middle of either middle tibia. As is the case with many other Diptera, the males of this species have the eyes closer together than do the females. The sides of the abdomen in the male are brownish near the base and grayish elsewhere. The females are grayish over the whole abdomen with a variable pattern of darker gray or black.

The filth fly, like all other Diptera, passes through four definite stages in its life cycle: egg, larva, pupa, and adult. The eggs of the fly (one or two hundred in number) are laid by preference in horse manure but may also be deposited in almost any moist decaying organic matter, such as "human excrement, pig manure, decaying grain, moist bran, moist mixtures of hay and grain from feed troughs of animals, excreta-soiled straw, contents from slaughtered animals, decaying kitchen refuse, rotting fruits and vegetables, excreta-soiled paper and rags, and ensilage." Dr. Howard estimates that probably 90% of our filth flies are hatched from horse manure. Only certain portions of a manure pile are, however, favorable for fly breeding, "a layer some inches deep and lying a few inches below the surface where there may be found a moderate amount of heat and moisture, an excess of either being fatal or compelling migration."

It takes the eggs of the fly about twelve hours, on the average, to hatch. The larvæ are whitish creatures, blunt at the posterior end and pointed in front. They have no bristles or hairs. On the blunt end are spiracles or breathing holes. In young larvæ these spiracles are in a heart-shaped aperture; later they appear in two slits; and still later in three winding slits. The changes occur when the larvæ cast their skins at intervals during their growth while feeding on the manure or other material in which they live.

About five days after hatching, the maggot, now about half an inch long, burrows downward into the ground or outward into the drier portions of the manure and there changes to a brownish pupa about ¼ inch long. The pupal stage may last from three or four days to several weeks, and recent observations suggest that autumn broods usually pass the winter in this form, although the fly may

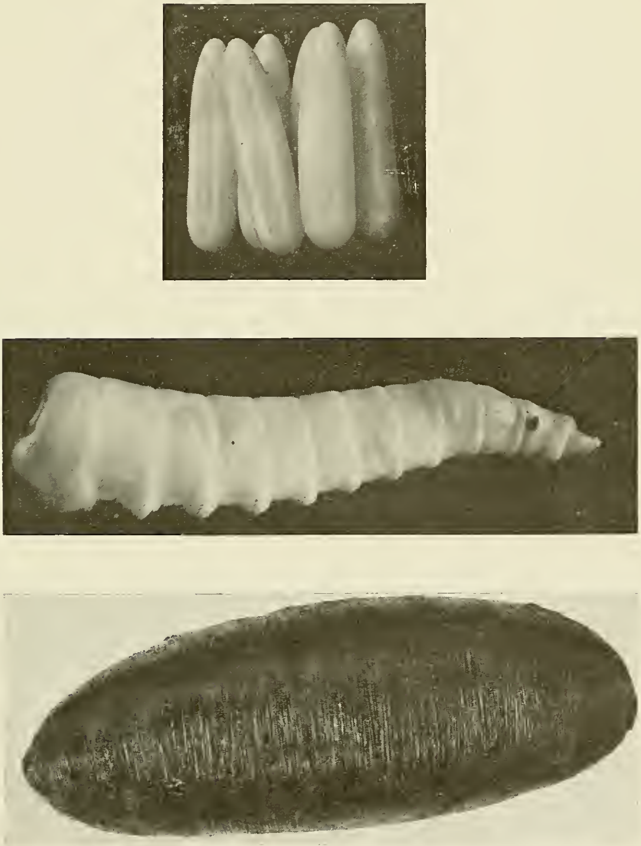

Fig. 2. EGGS, LARVA AND PUPA OF THE FILTH FLY
(Photograph of models in The American Museum of Natural History)

hibernate in any stage. At the termination of the pupal stage the fly comes out of the pupal case and crawls up to the surface of the material in which it pupated. Here its wings quickly harden and it is ready to fly away.

The rate at which generations of flies follow each other is determined by the temperature. Studies made in the Laboratory of Public Health of the American Museum gave a total period from egg laying to the emergence of the adult of 9.3 days at 35° C., 10.3 days at 30° C., and 22.3 days at 20° C.

The adult fly lives upon liquid food, since its mouth parts are in the form of a sucking proboscis, but by discharging a free flow of saliva it is able to turn foods like sugar into the fluid form it can absorb.

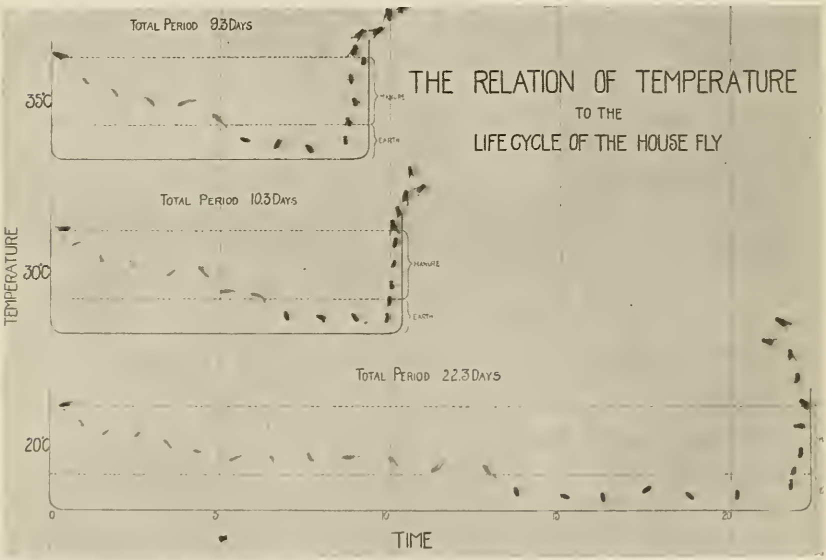


Fig. 3

Fig. 4. THE FILTH FLY (*Musca domestica*)
(Photograph of model in The American Museum of Natural History)

## RELATIVES OF THE FILTH FLY

There are a number of other flies sometimes found in houses which may be mistaken for the Filth Fly, and the characteristics of a few of them may be briefly described.

*Homalomyia canicularis* is often supposed to be a "young house fly." It does look like a small edition of the more common and dangerous insect; but it is a wholly different species. No insect grows after it has attained to the dignity of wings. The wing-veins of *Homalomyia* run without a sharp bend to the margin of the wing. This creature is really not even a muscid; it belongs to the Anthomyidæ. It breeds in waste organic matter such as manure.

Fig. 5. THE LITTLE HOUSE FLY
(*Homalomyia canicularis*)

*Muscina* is a muscid genus. Our species may be recognized by the fact that they are black flies and not shining; the median stripe on the thorax is light, the fourth longitudinal vein is only slightly bent and the first posterior cell is scarcely contracted at the margin; the hind end of the thorax may be reddish. *M. stabulans* has the legs and palpi more or less yellowish, while those of *M. assimilis* are wholly black. The larvæ feed on excrement and a variety of decaying substances including fungi and vegetables.

*Pollenia rudis* is known as the "cluster fly" from the habit which the adults have of congregating in masses, especially about the ceilings of rooms, when they are looking for a place in which to hibernate. When mashed, these flies are very greasy and have an odor which has been described by some as like honey and by others as "very disagreeable." They breed, as parasites, in earthworms. The thorax has no distinct stripes and is usually covered with a yellowish "dust"; the space between the eyes is white, the fourth longitudinal vein is sharply bent.

The genus *Lucilia* includes the "green- and blue-bottle flies." Both the thorax and abdomen are bright and metallic. This description would apply also to certain other Muscidæ, but it has not been

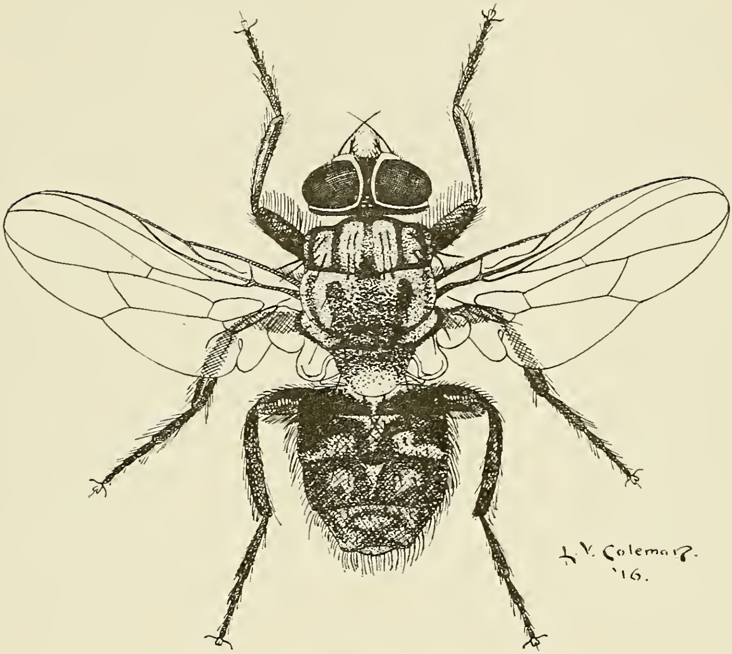


Fig. 6. THE STABLE FLY (*Muscina stabulans*)

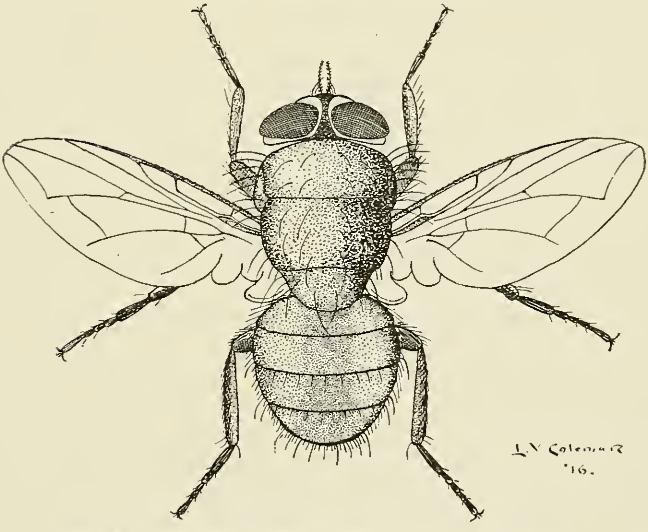


Fig. 7. THE BLUE-BOTTLE FLY (*Lucilia cæsar*)

shown that the "bottles" are instrumental in transmitting diseases and a further diagnosis would require going into details which would be out of place here. The larvæ feed chiefly on carrion but those of *L. cæsar* occur also in garbage and excrement.

These notes on various Muscidæ (in a broad sense) and an Anthomyid have been given for the purpose of introducing the table given below.[1] It will be seen from this table that the only fly which is very abundant on human excrement and also in dining rooms is *Musca domestica*. This is the principal reason why this fly is so dangerous.

Flies found in Dining Rooms

| Flies found on Human Excrement | Very Abundant | Abundant | Moderately Abundant | Rare |
|---|---|---|---|---|
| Very Abundant | *Musca domestica* | | | *Borborus equinus* |
| Abundant | | | *Muscina stabulans* | *Sarcophaga sarraceniæ*<br>*Ophyra leucostoma*<br>*Pseudopyrelia cornicina*<br>*Myospila meditabunda* |
| Moderately Abundant | | *Homalomyia canicularis* | *Lucilia cæsar* | |
| Rare | | | *Drosophila ampelophila*<br>*Stomoxys calcitrans* | *Pollenia rudis*<br>*Calliphora erythrocephala* |

[1]Reprint from the *Field Book of Insects* (G. P. Putnam's Sons), by Frank E. Lutz. It may not be out of place to say that this book gives further details, which cannot be included here, concerning the identification and habits of other insects which are troublesome but not actually dangerous.

## BITING FLIES

*Stomoxys calcitrans.* If ordinary house flies seem to be adding to their other vices by biting, it is a case of mistaken identification; the culprits are almost certainly the *Stomoxys calcitrans*, the "biting stable fly." Its proboscis is long, slender, and pointed, not fleshy and blunt as is that of *Musca domestica* (page 5). The name, stable fly, is not very appropriate, as this fly is neither the most abundant fly about stables, as a rule, nor does it breed chiefly about stables unless a quantity of wet, fermenting hay or straw be present. Piles of lawn-cuttings or of weeds furnish more *Stomoxys* than do ordinary stables. Adults are more frequently found about buildings in damp weather and just before a storm than at other times, for which reason the saying has arisen that the biting of flies is a sign of a storm. The best method of control is self-evident—do away with the breeding places either by destroying the material, covering it so that flies do not have access to it, or drying it so that the larvæ cannot live.

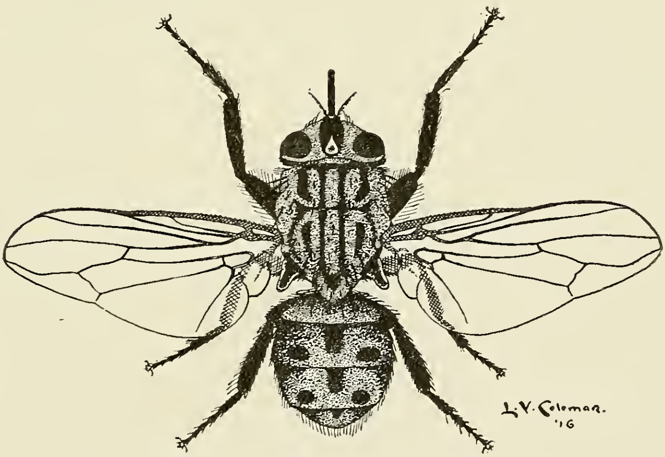


Fig. 8. THE BITING STABLE FLY (*Stomoxys calcitrans*)

The most conspicuous biting flies in the Northeastern United States belong to the Tabanidæ and are variously called "horse flies," "gad flies," and "green-headed flies." The head is large; each antenna has three joints, the last being somewhat subdivided into from four

to eight parts; the eyes are large and usually brightly colored when the insect is alive; the proboscis is sometimes as long as, or longer than, the body; the thorax and abdomen bear hairs but not bristles; each wing has two submarginal and five posterior cells; the anal cell is usually closed but not far before the border of the wing; the marginal vein runs entirely around the wing. The larvæ are aquatic, or semi-aquatic, and predacious. They taper at both ends and each of the eleven segments into which the body is divided bears a circlet of small spines. The adults fly by day, usually being found in warm sunny places, though some prefer shady woods. Only the females bite; both sexes feed on the juices of plants and on similar substances. There are several hundred species recorded from North America.

The only other biting Calypterate which we have in the Northeast is *Hæmatobia serrata*, the "Horn fly." It is less than half the size of *Stomoxys calcitrans* and the palpi are nearly as long as the proboscis, while in *Stomoxys* they are much shorter than the proboscis.

The genus *Glossina* includes the tsetse flies; it is found only in Africa at the present time, although it formerly occurred in America, as is proved by fossils unearthed in Colorado. The tsetse flies are as large as, or larger than, *Musca domestica*, the ordinary house fly; the waist is constricted; the wings are crossed when at rest; the fourth longitudinal vein bends before it meets the very oblique anterior transverse vein. Both sexes bite, usually by day, but also at night if the moon be bright. The larvæ almost complete their development within the body of their mother and are then laid at the roots of plants. The pupal stage lasts from six to eight weeks. Several species have been described and their habits carefully studied but, owing to the facts that the larvæ are carried by the female until nearly or quite full-grown and that the adults feed on the blood of other animals than man, control methods are difficult.

Certain insects are not real transmitters of disease but are themselves its inciting agents. There are, for instance, dipterous larvæ, "maggots," which occur by accident or as a part of their normal life-history in the human body. Such an occurrence is called myiasis. The most important species in this connection is the "screw-worm," *Chrysomyia macellaria*. It is a blow fly which has been classed with the Muscidæ and also with the Sarcophagidæ. The adult fly is nearly, or quite, half an inch long; metallic green; with three longi-

tudinal dark stripes on the thorax; its head is reddish to yellowish brown; its wing venation is similar to that of *Musca domestica*. Several hundred eggs (sometimes the eggs hatch before they are laid and then living larvæ are deposited) are placed on carrion or in wounds or sores in living animals. In the case of man, the eggs are usually laid in the nostrils of those suffering from nasal catarrh. The yellowish-white larva has rings of bristle-like structures on the segments, which give it the appearance of a screw. If it is not removed from the nostril, it may work in, causing an abscess and even death. Blow flies of the genus *Calliphora* (Muscidæ with metallic colored abdomen but dull colored thorax; fourth longitudinal vein sharply bent; distal third of antennal bristle bearing some hairs; cheeks unicolorous) sometimes lay their eggs on cold meat, especially pork, and the larvæ are then taken into the stomachs of careless eaters. Usually not much harm is done. The same is true of *Lucilia* (see page 10). The Œstridæ are closely related to the Muscidæ but the adults have rudimentary mouth-parts. They are the bot flies, and certain species do great damage to stock. In tropical America human beings are parasitized by the Œstrid *Dermatobia hominis*, and possibly other species. The larvæ live underneath the skin of various parts of the body. William B. Herms, in his useful *Medical and Veterinary Entomology* (Macmillan Medical Co., New York), gives a key to the larvæ ordinarily involved in myiasis.

## THE FILTH FLY AND DISEASE

*Musca domestica* is not only a pest but a serious menace to health on account of the likelihood that it may carry filth from the unsavory places which it frequents to food. The foot of the fly is tipped with claws and soft pads on which there is ample room for great numbers of microbes to be transplanted; and, as a matter of fact, if a fly be allowed to walk over the surface of a properly prepared bacterial culture plate, the path over which it travels is marked by numerous

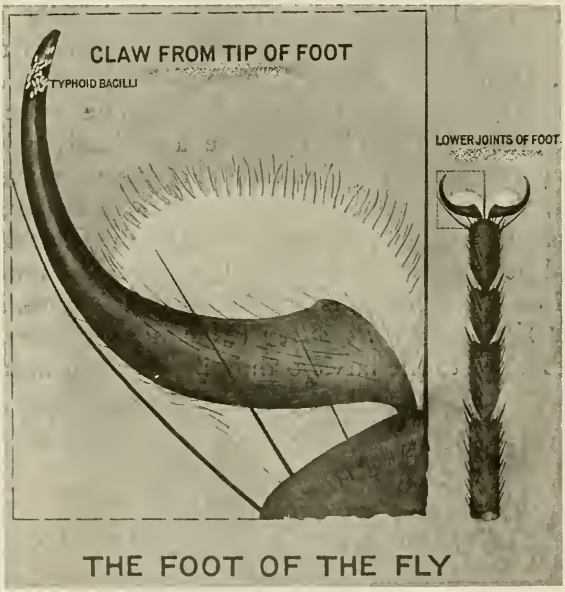


Fig. 9

colonies of bacteria, each developed from a single germ planted there by the foot of the insect. Even more serious, perhaps, is the danger that disease germs ingested by a fly from privy contents, or other infected material, may be voided in its excrement (fly specks) or in small droplets which are regurgitated by the insect. Experiments have shown that many kinds of disease germs may pass through the intestines of the fly and be discharged in its excrement in an active and virulent state.

The spoiling of foods may obviously be hastened by ordinary putrefactive germs introduced in such ways and, if the fly has been feeding upon human discharges (tuberculous sputum for example, or the contents of an outside closet used by an incipient typhoid case) specific human diseases may easily result.

Fig. 10. BACTERIAL COLONIES DEVELOPED ON AN AGAR PLATE FROM GERMS PLANTED BY THE FEET OF A FLY WHICH WALKED OVER IT

The number of microbes actually carried by flies varies greatly with the general amount of filth in their surroundings. Studies made by the New York Association for Improving the Condition of the Poor gave an average of 13,986 bacteria per fly (on the outer surfaces of its body) in clean localities, against 1,106,017 in dirty surroundings. The germs of typhoid fever and Asiatic cholera have been isolated from the bodies of flies caught during epidemics of these diseases, and we have, in our museum of living bacteria at the American Museum, one strain of typhoid bacilli isolated in this way in the course of an outbreak in New Jersey.

It was the experience of the American troops in the Spanish War which first forcibly called attention in this country to the danger of the transmission of disease by flies. About one out of five of our volunteer soldiers contracted typhoid during the campaign, and the investigators who studied the cause of this disastrous affair concluded that "the number of cases of typhoid fever in the different camps varied with the methods of disposing of the excretions." The typhoid germs, in most cases, were probably spread from person to person by more or less direct contact, but the fly undoubtedly played its part. Doctors Reed, Vaughan and Shakespeare pointed out in their official report that "flies swarm over infected fecal matter in the pits and then deposit it and feed upon the food prepared for the soldiers at the mess tents. In some instances, where lime had recently been sprinkled over the contents of the pits, flies with their feet whitened by lime were seen walking over the food."

The investigators also point out that, "Officers whose mess tents were protected by means of screens suffered proportionately less from typhoid fever than did those whose tents were not so protected," and again that "Typhoid fever gradually disappeared in the fall of 1898 with the approach of cold weather and the consequent disabling of the flies."

In the World War flies have constituted a grave menace to the health of troops operating in tropical and semitropical regions. On the western front they have been remarkably well controlled by burning manure and garbage and by protecting latrines. At Gallipoli and in Egypt, however, they have been responsible for the spread of dysentery and many other parasitic diseases among the French and English troops.

The most striking evidence in regard to the importance of the fly as a carrier of disease is, perhaps, that furnished by the experience of Jacksonville, Fla. Ever since the encampment of troops at Jacksonville in 1898 the city has been heavily infected with typhoid fever. No reliable data are available before 1908, but the typhoid death rates per 100,000 population for the years 1908, 1909, and 1910 were 82, 75 and 106 respectively. In the late summer of 1910 a law was passed requiring that all dry closets within the city should be rendered fly-proof. By March, 1911, about 75 per cent. of the closets had been brought into conformity with the law and the typhoid rate for the year dropped to 63. By January, 1912, practically all the closets had been rendered fly-proof and the typhoid rate dropped to 26.

The danger of transmission of disease by flies increases with the extent to which human excreta are exposed to the access of flies and with the duration of the warm season, which favors fly breeding. Danger is not confined, however, to unsewered rural districts or to the South. The Association for Improving the Condition of the Poor in New York City made a careful study of the relation between flies and infant diarrhea in the summer of 1914. Nearly 1000 infants were carefully observed, half of them being in ordinary homes and half in homes where special efforts were made to protect the infant and his food from flies. The homes studied were classified according to their general cleanliness and according to their freedom from flies. In the homes where flies were abundant, 1.9 times as many infants suffered from summer diarrhea as in the homes protected from flies, and 1.8 times as many were attacked under dirty conditions as in the clean homes. Where both factors were combined, in dirty and fly-ridden homes, there were 2.4 times as many infants who suffered from diarrhea as in the clean and fly-protected tenements.

## PREVENTION OF FLY-BORNE DISEASE

The practical methods of controlling the spread of disease by flies fall under four main headings: the prevention of fly breeding, the destruction of adult flies, the protection of human discharges from access of flies, and the protection of food by screening houses and covering the food itself.

## PREVENTION OF FLY BREEDING

The usual methods employed in fighting the dangerous Muscidæ are really of little avail. Sticky fly-paper, wire flytraps, and poisons will undoubtedly kill a large number but infinitely more are breeding where they came from. Screening our windows and doors will undoubtedly keep many out but it is not pleasant to live in a cage. Furthermore, the people from whom we buy our milk and other food-stuffs may not be so careful. The only thoroughgoing method is to stop the trouble at its source—prevent fly breeding. The adults we kill cannot thereafter breed, but they have probably done so before and many of their companions are sure to escape altogether. If we could do away with the breeding places, or make them unfit for fly larvæ, or keep adult flies away from them, the thing would be done. Nearly all the books and lecturers say that this is easy. It is well to be optimistic but better to recognize the whole truth. It cannot be done easily.

If anti-fly campaigns are to be successful your neighbor must keep his place clean too, for his flies are just as apt to come into your house as his, so the problem becomes one for the whole community. This is the heart of the matter. A few earnest individuals or well-meaning Improvement Societies, by themselves, can do little more than cause a great deal of trouble and very little good. Laws must be made and enforced so that the ignorant or careless may not make of little or no avail the work of the intelligent and careful.

Since 90 flies out of every 100 are probably born in a manure pile, the elimination of the natural breeding places of the fly means, first and foremost, the proper care of stable manure. Stables should not have dirt floors, since it has been shown that the ground moistened by animal discharges contains many larvæ and pupæ. Floors should be water-tight, preferably of cement, and constructed so as to drain freely into a sewer or covered cement pit. In wooden floored stables flies should be excluded from the ground beneath the floor boards. Openings left for ventilation should be screened with wire and no holes should be bored in the floor for drainage of urine.

Fig. 11. MODEL SHOWING A GOOD TYPE OF MANURE BIN
(American Museum of Natural History)
The surface of the manure is being sprinkled with a chemical to prevent fly breeding.

It has generally been recommended that the manure itself should be kept in a dark vault or pit from which flies are shut out by screens, or in a tight covered box. The health officer of Asheville, N. C., where an unusually successful anti-fly campaign has been carried out, believes that screening of manure has been over-emphasized and that tightly floored boxes and thorough and complete cleaning up of these floors at frequent intervals are the main desiderata. He points out that most manure already contains fly maggots when placed in the bin and that an elaborately screened bin is hard to clean so thoroughly that development may not take place in the manure left behind.

A method of storing manure which is specially applicable to military camps depends on the fact that flies cannot breed readily in this material when it is closely packed. A rectangular area of ground is staked off and the manure is built up into compact heaps, the sides being kept straight and beaten hard with shovels. The adjacent ground is also beaten hard and loose straw is placed in small windrows about a foot from the edge. The absence of air in the interior of the heap, with the high temperature and chemical products due to bacterial fermentation, makes the manure highly unfavorable for fly development, and any larvæ which succeed in developing in the surface layer will pass out and pupate in the ring of straw, which should be swept up every two or three days and burned.

The United States Bureau of Entomology has devoted special attention to the problem of chemical treatment of manure for the purpose of poisoning the maggots which might otherwise be bred therein. Any one who is interested in the control of this insect pest should write to the Bureau of Entomology, Washington, D. C., and to the Department of Agriculture of his own State, for the latest recommendations in regard to this method of treatment, which is constantly being improved and made more economical and efficient. The following suggestions are taken from Farmers' Bulletin 851 of the United States Department of Agriculture and represent the best procedures available in 1917.

For manure or other refuse not to be used as a fertilizer, powdered borax is the best chemical preventive of fly breeding; .62 pound per 8 bushels of manure, or about 1 pound per 16 cubic feet, will destroy 90 per cent. of the larvæ present. The borax should be applied in solution, or water should be sprinkled on after scattering dry borax evenly over the pile.

Borax-treated manure in large amounts may injure crops; and, for manure which is to be used on the land, powdered hellebore may be recommended. A water extract is prepared by adding ½ pound of powder to every 10 gallons of water, stirring and allowing to stand for 24 hours. The stock mixture thus prepared is sprinkled over the manure at the rate of 10 gallons to every 8 bushels (10 cubic feet) of manure. Hellebore, while more expensive than borax, in no way injures the manure.

A third alternative has been suggested by the Department of Agriculture, which, while showing a still higher first cost, involves the use of substances which serve directly to increase the fertilization value. A mixture of ½ pound of calcium cyanamid plus ½ pound of acid phosphate to each bushel of manure killed 98 per cent. of the larvæ when scattered evenly over the surface and wetted with water, at the same time adding to the manure the valuable elements nitrogen and phosphorus.

"It is well to bear in mind that the house flies breed in many substances other than horse manure, for example, in pig manure, chicken manure, ensilage, moist bran, rotting potatoes, and in decaying matter on the public dumps of towns and cities, and it is necessary to give attention to all such accumulations where active fermentation is taking place."

A highly ingenious method of preventing breeding of flies in manure is the maggot trap devised by Dr. E. C. Levy, Health Officer of Richmond, Va. Its use is described by Mr. Hutchinson of the United States Bureau of Entomology as follows:

"The maggots of the house fly, when they have finished breeding, show a distinct tendency to migrate and will crawl away from the manure, especially if it is moist, in search of a comparatively dry and safe place to pass the pupal or resting stage. Now, if the manure is placed on a slatted platform, and if the platform stands on the floor of a concrete basin containing ½ inch or more of water, the larvæ in migrating will drop into the water and be drowned. Each day the stable cleanings should be placed on the platform and compactly heaped and well moistened. For the purpose of keeping the manure wet, it is best to have a small cistern close to the platform and a pump so placed that the watering of the manure heap is easily accomplished. If the liquid manure from the stables is conducted by drains to the cistern, the valuable plant food which it contains will thus be added to the manure on the maggot trap. Experiments have

Fig. 12. TRAP FOR THE DESTRUCTION OF FLY LARVÆ
(Maggot Trap)

shown that the maggot trap will destroy 99 per cent. of the maggots developing in manure. After the manure has been standing on the maggot trap for 10 days it will be practically free from maggots and may be used on fields or gardens or stored in heaps without likelihood of any further breeding taking place in it. The advantages of the maggot trap are that it is cheap, requires little extra labor to operate and to dispose of the drowned maggots, and it does not lessen the value of the manure but rather tends to preserve it. As is the case with all other methods, the use of the maggot trap must be supplemented by careful attention to possible breeding places other than horse manure."

### 2. Destruction of Adult Flies

Simple and effective flytraps may be used to some advantage in decreasing the number of flies. Their use has been advocated not only because of their immediate results, but because of the chance that the flies may be caught before they lay their first batch of eggs, and that thus the possible number of future generations will be materially reduced.

Many types of flytraps are on the market, and as a rule the larger ones are the more effective. Anyone with a few tools, however, can construct flytraps for a small part of the price of the ready-made ones. A trap which is very effective in catching flies, and is easily made, durable, and cheap, may be constructed as follows:

"The trap consists essentially of a screen cylinder with a frame made of barrel hoops, in the bottom of which is inserted a screen cone. The height of the cylinder is 24 inches, the diameter 18 inches, and the cone is 22 inches high and 18 inches in diameter at the base. Material necessary for this trap consists of four new or second-hand barrel hoops; one barrel head; four laths; 10 feet of strips 1 to 1½ inches wide by ½ inch thick (portions of old boxes will suffice); 61 linear inches of 12- or 14-mesh galvanized screening 24 inches wide for the sides of the trap, and 41 inches of screening 26 inches wide for the cone and door; an ounce of carpet tacks, and two turn buttons, which may be made of wood." The cost of the material for this trap is not great, and in many cases the barrel hoops, barrel head, laths and strips can be obtained without expense.

"In constructing the trap, two of the hoops are bent in a circle (18 inches in diameter on the inside) and nailed together, the ends being trimmed to give a close fit. These form the bottom of the frame

(A), and the other two, prepared in a similar way, the top (B). The top (C) of the trap is made of an ordinary barrel head with the bevel edge sawed off sufficiently to cause the head to fit closely in the hoops and allow secure nailing. A square, 10 inches on the side,

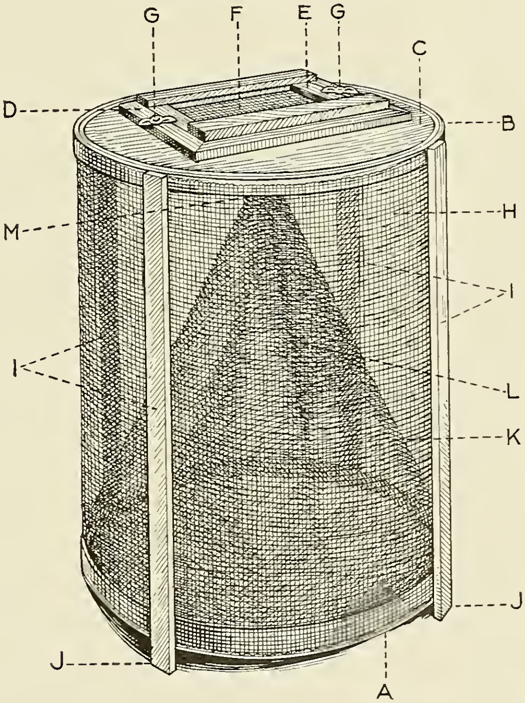


Fig. 13. A SIMPLE FLYTRAP (see text)

is cut out of the center of the top to form a door. The portions of the top (barrel head) are held together by inch strips (D) placed around the opening one-half inch from the edge to form a jamb for the door. The door consists of a narrow frame (E) covered with screen (F) well fitted to the trap and held in place (not hinged) by buttons (G). The top is then nailed in the upper hoops and the sides (H) formed by closely tacking screen wire on the outside of the hoops. Four laths (I) (or light strips) are nailed to the hoops on the outside of the trap to act as supports between the hoops, and the ends are allowed to project 1 inch at the bottom to form legs (J).

The cone (K) is cut from the screen and either sewed with fine wire or soldered where the edges meet at (L). The apex of the cone is then cut off to give an aperture (M) 1 inch in diameter. It is then inserted in the trap and closely tacked to the hoop around the base."

The effectiveness of the traps will depend on the selection of a good bait. For attracting house flies beer is probably the best. It loses much of its attractiveness after the first stages of fermentation are over, and for this reason it should be renewed every day or two. Milk is also a good bait. Over-ripe or fermenting bananas, crushed and placed in the bait pans, give good results. A combination of bananas and milk is more attractive than either used separately. A mixture of 3 parts water and 1 part cheap molasses is very attractive after it has been allowed to ferment for a day or two. A mixture of equal parts of brown sugar and cheese (or curd of sour milk), thoroughly moistened, give good results after it has been allowed to stand for three or four days. For catching blow flies and other meat-infesting flies, the best bait is the mucous membrane from the lining of the intestines of hogs. Ordinary fish or meat scraps may be used.

Fly paper is sometimes helpful, particularly the long slender roll of sticky paper hung from a ceiling. For a fly poison, Professor Phelps of the United States Public Health Service recommends either formaldehyde or sodium salicylate, three teaspoonfuls of the 40 per cent. commercial solution of formaldehyde, or the same amount of powdered sodium salicylate to a pint of water. Nearly fill a glass tumbler with the solution, place over this a piece of blotting paper cut to circular form and somewhat larger in diameter than the tumbler, and over this invert a saucer. Invert the whole device. The blotting paper will remain in the proper moist condition until the entire contents of the tumbler have been used and the strength of the formaldehyde solution will be maintained. A little sugar sprinkled upon the paper will increase the attractiveness of the poison for the flies. Either of these preparations may be safely used where there are young children, although the addition of the sugar is not recommended in such cases.

The killing of flies in the house by "swatters" is also of some value, although where the insects are abundant the majority of them should be eliminated by the more efficient methods of trapping.

Among natural enemies which help to destroy flies in either the larval or the adult state are hens, swallows, phœbes and other birds, and toads.

### 3. Protection of Human Discharges from Access of Flies

The measures suggested above will greatly reduce the numbers of flies but, as a rule, will not do away with them entirely. It is, therefore, always essential to take precautions against the spread of specific human diseases by guarding intestinal discharges from the access of flies. Outside closets, where they cannot be replaced by a cesspool or sewer system, should always be carefully constructed so as to exclude insects, all openings for ventilation screened, and cracks in walls or openings below the floor level tightly closed. In the army, the construction of fly-proof latrines is a first essential of camp sanitation.

### 4. Exclusion of Flies from Houses and from Access to Food.

Finally, flies should be excluded from dwellings by careful screening of doors and windows. Screens must be always in place and must fit tightly. In particular, the kitchen and the dining room should be protected in this way.

The covering of foods in stores and restaurants is one of the most important aspects of the campaign for clean and pure foods, and it is wise to avoid all such places where flies are abundant and food unprotected.

## THE MOSQUITOES AND THEIR ALLIES

The blood-sucking habit, and the modifications of mouth-parts necessary to such a habit, are to be found in several, not closely related, groups of the two-winged insects, Diptera. All blood-suckers are to be looked on with suspicion, because of the possibility that they may be the intermediate hosts of disease-parasites. Several such insects have already been mentioned; but another group of quite different creatures remains to be discussed.

If a moquito, crane fly, or some similar insect, be carefully examined, it will be seen that the antennæ ("feelers") consist of not less than eight joints, rather similar one to another; the antennæ are usually longer than the thorax (the middle part of the body, the part which bears the wings and legs); the anal cell (see Fig. 14) is rarely narrowed in the border of the wing and the discal cell is usually absent. These are distinguishing characteristics of the nematocerous Diptera or Orthorrhapha, that group of Diptera to which mosquitoes, punkies, black flies, and blood-sucking gnats in general belong.

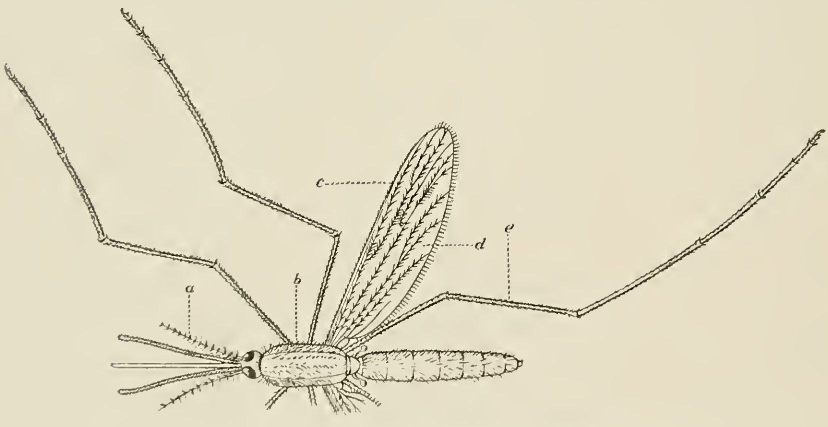


Fig. 14. STRUCTURAL CHARACTERS OF THE MOSQUITO

a. Antenna b. Thorax
c. Costal vein of wing d. Anal cell
e. Tibia

Of the Nematocera, there are four families (Culicidæ, Psychodidæ, Simuliidæ, and Ceratopogonidæ) which contain blood-sucking species. The adults of the first two of these, Culicidæ and Psychodidæ, unite in typically having the following characteristics: at least nine

veins extend to the margin of each wing; the top of the thorax does not have a distinct V-shaped suture near the middle; the costa (Fig. 14) continues around the hind margin of the wing; and the wing veins bear conspicuous, scale-like hairs. The Culicidæ (Mosquitoes) are slender; they have long, slender, usually moderately hairy or scaly legs; their tibiæ (the second large joint of the legs) have apical spurs; the wings are elongate and narrow. The Psychodidæ (Moth-flies) are small and robust; their legs are short and densely hairy; the tibiæ have no apical spurs; the wings are short, broad, and sometimes pointed apically. The Simuliidæ and Ceratopogonidæ have more than four distinct longitudinal veins but less than nine veins extend to the margin of each wing, and the wings do not have a network of fine creases; the costal vein does not continue beyond the apex of the wing; and there are no ocelli (small, simple eyes which, when present, are situated between, often above, the conspicuous compound eyes). The Simuliidæ (Black-flies, etc.) are usually very small and thick-set; the antennæ are shorter than the thorax; each antenna is composed of ten or eleven closely united segments, not plumose; the hind pair of legs are more or less dilated; the anterior veins of the wings are stout, the posterior ones weak. The Ceratopogonidæ (Punkies), like the Chironomidæ with which they were formerly united but from which they have been separated because of their piercing mouth-parts, are slender delicate gnats; the antennæ are slender, the joints more or less constricted and sometimes plumose; the femora of the slender legs are sometimes thickened.

General notions are not always safe guides in the classification of insects. However, our general notions as to what a mosquito is, combined with the discussion in the preceding paragraph, will probably suffice to enable us to recognize a culicid. No male of any species of Culicidæ ever "bites." The females of most of the species with which we come in contact have the ability and desire to pierce the human skin with their needle-like mouths, if they get a chance, and to suck a small drop of blood. If this were all they did, it would be bad enough, but, when they pierce the skin, they inject an irritating substance, saliva, which sometimes "carries with it the microscopic, unicellular animals which cause malaria, and down this minute, microscopic [salivary] duct has flowed the fluid which has altered the fate of continents and played a conspicuous part in the destruction of the ancient civilizations of Greece and Rome" (Shipley).

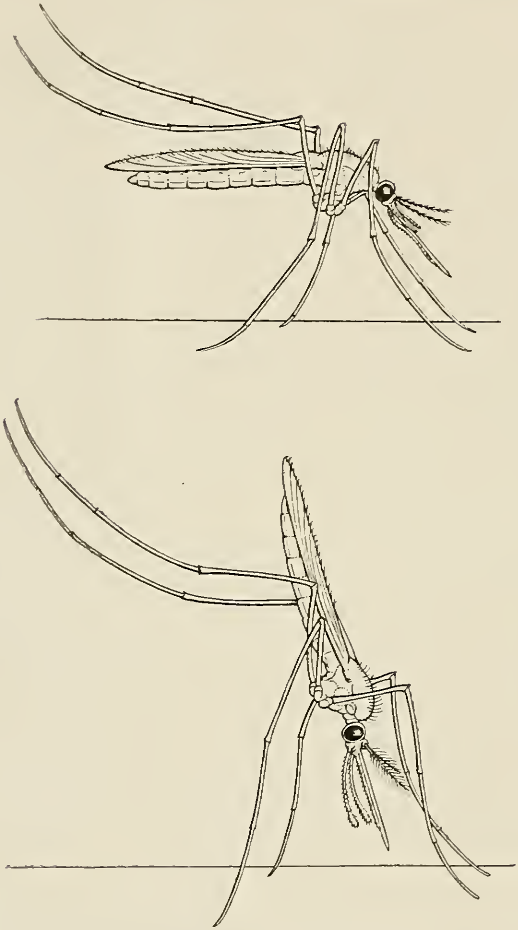

Fig. 15. RESTING POSTURE OF CULEX (above) AND ANOPHELES (below)

The disease-bearing and rest-disturbing habits of mosquitoes have led to a detailed and almost feverish study of their taxonomy. Species have been named and genera erected on the basis of characters which are very difficult for the non-professional to use. Formerly, the common species of true mosquitoes inhabiting the northern part of the United States were divided into two genera: *Anopheles* and *Culex*. As *Anopheles* contains the malarial mosquito

(or mosquitoes) it is the more important in the present connection, although not so numerous in species as the old, inclusive, *Culex*. Not all species of *Anopheles* have spotted wings, and not all spotted winged mosquitoes are *Anopheles*, but, for practical purposes and especially in the northeastern United States, we may say that mosquitoes with spots on their wings are *Anopheles* and that those with plain wings are something else. Furthermore, the adults of *Anopheles* are given to holding their beaks in a line with their bodies while *Culex* points the beak downward at an angle to the body-line. One of the technical points used in identifying adults of *Anopheles* concerns the relative lengths of the palpi and beak. The palpi are delicate, thread-like organs, one on each side of the beak. In the male the palpi are more feathered than in the female; this is even more true of the antennæ, or "feelers." Both sexes of *Anopheles* have the palpi nearly, or quite, as long as the beak; the females, at least, of our other mosquitoes have the palpi relatively short, rarely exceeding half the length of the beak. If one extends the three first fingers, the middle finger may be taken to represent the mosquito's beak and the other two fingers the pair of palpi of *Anopheles*. If, now, the first and ring fingers be bent at the end of the first joint, the three fingers, as viewed from above, may serve as a model of the relative lengths of the palpi and beak of the female *Culex*. In applying this test, be careful not to confuse the antennæ with the palpi.

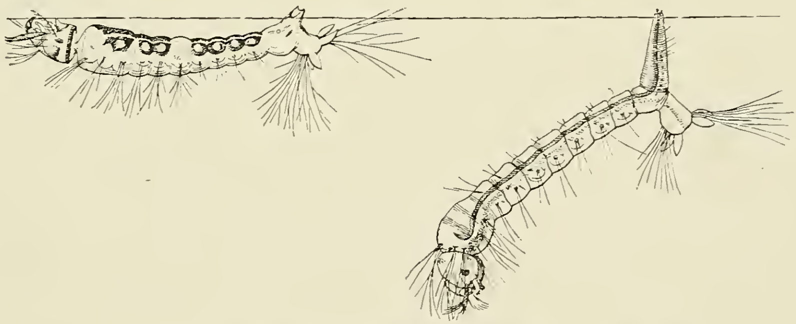

Fig. 16. RESTING POSTURE OF MOSQUITO LARVÆ; ANOPHELES (left); CULEX (right)

Mosquito larvæ live only in water but the females of certain species display what might almost be called foresight; they lay their eggs on ground which will later become covered with water, as on the mud of low places along a salt-marsh. The most familiar mos-

quito eggs are those of the rain-barrel species—eggs which are laid on end, side by side, in a boat-shaped mass on the surface of the water in barrels, tubs, and similar places. The eggs of *Anopheles* are laid singly but frequently they float close to each other, the floating being favored by special structures along their sides. The larva, or "wriggler" which hatches from an egg of *Anopheles* has a very short breathing siphon on its back at the tail end. The larva is lighter than water; when feeding or at rest, it floats just below the surface and parallel to it; when disturbed it wriggles vigorously from side to side, the motion sometimes carrying it downward but more frequently sideways. When at the surface, the end of the breathing siphon pierces the "surface film," opens up, and exposes the ends of the tracheæ, the tubes which convey air to all parts of the creature's body. In order to feed on the microscopic plants and other organic material floating at the surface, the larva twists its neck until its mouth is on a line with its back. While there are other, more technical characters, it is sufficient to say that a mosquito larva which has a short, stubby breathing siphon, floats parallel with the surface of the water, and twists its head to feed is an *Anopheles*. The *Culex* larva floats at an angle with the surface as shown in Fig. 16, and has a relatively long breathing siphon.

As a young insect feeds, its flesh increases but its skin does not stretch sufficiently to accommodate the enlarging body. Therefore, the old skin is cast from time to time and a new, larger skin is formed. Finally there comes a time, as in the case of such insects as moths and beetles, which like the Diptera have a "complete metamorphosis," when there emerges from a larval skin something which is neither larva nor adult, and which is called the pupa. The pupa of moths is, for the most part, immobile and frequently enclosed in a protective case, the "cocoon," which is spun for it by the larva. The pupa of mosquitoes is active, but not so active as a larva, and it does not feed. It also differs from the larva in being hunched up instead of slender and in having a pair of breathing siphons on its thorax (the part of the body just back of the head) instead of a single siphon on the tail. The pupa of *Anopheles* closely resembles that of *Culex*, but the abdomen is more sharply curved and the breathing siphons are more dilated at the top and relatively shorter than in *Culex*. The adult mosquito finally emerges from a split in the back of the cast pupal skin, which forms a miniature boat upon which the

adult may stand while stretching itself before it flies away to perpetuate its species, perhaps at the expense of ours. Studies on a common fresh-water mosquito (*Culex pipiens*) made at the American Museum showed that at 20° C. the cycle was completed in 19.6 days, at 25° in 11.7 days, and at 30° in 7.8 days.

In the vicinity of New York City there are three fairly common species of *Anopheles: punctipennis*, *crucians*, and what was formerly called *maculipennis*, more recently *quadrimaculatus*, but which probably should be called *guttulatus*. Remembering Pope's advice concerning the choice between the old and the new, we will use the name *quadrimaculatus*.

*Anopheles punctipennis* is "a medium sized dark brown mosquito with the upper surface of the thorax dark brown at the sides and with several narrow lines of yellowish gray hairs appearing as one broad gray stripe in the center. The beak and legs are unbanded; the wings densely clothed with black and yellow scales, two large black patches and two smaller ones on the front margin especially conspicuous. The abdomen is dark brown, profusely scattered with yellowish brown hairs" (Smith). The other two species to be mentioned here have no whitish spot on the front margin of the wings.

*Anopheles crucians* "is brown, not quite as dark as *punctipennis*, with the thorax striped with grayish scales, the wing veins clothed with whitish and black scales, the black ones especially collected along the wing margin" (Smith). The hindmost wing vein has three black spots separated by two yellowish-white ones. This mosquito flies earlier in the evening and later in the morning than either *punctipennis* or *quadrimaculatus*, and has, for this reason, been called the Daylight *Anopheles*.

*Anopheles quadrimaculatus* may be recognized by the four small dark spots on each of its yellowish wings. It is the species usually thought of in connection with malaria in this country and it has been observed to breed in brackish water as well as fresh.

Little need be said concerning the other mosquitoes of northern regions, in connection with disease. They are troublesome on account of their biting habit, and for the same reason they are to be looked on with suspicion since they may be the unknown carriers of some disease. The females have relatively short palpi and the larvæ relatively long breathing siphons. In the South, however,

there are certain very important species. *Culex quinquefasciatus*, also known as *fatigans*, extends as far north as Washington and St. Louis, its larvæ replacing the northern *pipiens* in the rain-barrels. In both species the eggs are laid in boat-shaped masses floating on the surface of the water. The wings of both species are clear and both species have white cross-bands on the abdomen; these abdominal bands are joined to lateral spots in *pipiens* but separated from the lateral spots in *quinquefasciatus*.

*Aëdes calopus*, formerly called *Stegomyia fasciata*, the Yellow-fever Mosquito, is frequently carried by vessels into temperate regions but it has not succeeded in establishing itself there. The adult flies by day instead of by night. *Aëdes* is a genus which is separated from *Culex* by characters rather difficult for the layman to make out. Some of our common salt-marsh mosquitoes are now put in this genus. The following list of characters will probably differentiate *calopus* from anything with which it is likely to be confused; the claws on the front and middle feet of the female are toothed; the joints of the black feet are white-ringed, but at the bases only; the beak of the female is not white-ringed; the thorax is not markedly paler than the abdomen and bears silvery-white lines in the pattern of a lyre, but no median white line; the abdomen has distinct, segmental white bands which are continuous across the abdomen; the wing-scales are narrow and mostly brown.

Howard and others, in their report on mosquitoes published by the Carnegie Institution, say concerning *calopus*: "Under natural conditions the eggs are laid singly in small irregular groups some distance above the margin of the water..... The larvæ live in accumulations of water in artificial receptacles. From being originally a tree-hole-inhabiting species, it is now wholly domesticated, and its larva inhabits artificial accumulations of water either within houses or in the vicinity of human habitations. Occasionally the larvæ occur in holes in trees, but always in proximity to habitations. Goeldi has found the larvæ in water held by bromeliads, presumably near houses, and by the still folded leaves of banana plants. In the tropics the earthen jars in which drinking water is kept within dwellings are favorite breeding-places; the larvæ have the habit of keeping to the bottom, and, as these jars are never emptied, their presence is not even suspected. Water may be poured from the small earthen bottles used in hotels in the tropics, and, unless the bottle is quickly and completely emptied, the larvæ will remain

behind. Holy-water founts in churches are a favorite breeding-place. Out of doors the larvæ occur in tanks, barrels, rain-barrels, rain-troughs and discarded bottles and tins. The larvæ, when suspended from the surface film, hang nearly perpendicular..... Unlike many other mosquitoes they (the adult females) emit no sound when about to bite. The male likewise persecutes man and this has led to a widely quoted statement of Ficalbi that it sucks blood; however, it does not pierce the skin but laps sweat from the surface and in this way causes some irritation."

Several other families of nematocerous Diptera should be briefly mentioned on account of their blood-sucking habits.

**Psychodidae.** Some of the characteristics of this family were given on page 29. The most common—possibly the only—genus found in the vicinity of New York City is *Psychoda.* Its larvæ live in decaying vegetable matter, exuding sap, cow dung, and other moist excrementitious matter. The small, moth-like adults run well but fly weakly. They feed largely on nectar and rarely, if ever, "bite" animals, although they may sip fluids from wounds. In the tropics there is a genus, *Phlebotomus*, in which the species have the proboscis rather elongated and these do pierce the skin of man and other animals for the purpose of sucking blood. Some of these species are believed to be instrumental in the transmission of disease.

**Simuliidae.** See page 29 for some of the characteristics of the family. The species have received various common names including "buffalo gnats," "black-flies," "sand-flies" and "turkey gnats." The principal genus is *Simulium* and, although there are not many species, individuals sometimes occur in countless hordes. The larvæ live in running water, usually where the current is swiftest. There the larvæ sit on their tails catching for food the organic matter which the stream floats to them. They are often so numerous that the object on which they are gathered seems to be covered with moss. Unfortunately, the bite of the adult is not in proportion to its small size and when hundreds of bites are received in one day it is easy to believe the reports of deaths of both cattle and human beings from the bites alone. In addition to this, they have been suggested as possible carriers of anthrax to cattle and of pellagra to man.

The Ceratopogonidæ were mentioned on page 29 because of their biting habits; they have not, as yet, been connected with any disease. The species of *Culicoides* are the blood-sucking "punkies" or "no-see-ums." The larvæ are aquatic.

## MOSQUITOES AND MALARIA

Few diseases have, until recent times, seemed more mysterious than malaria. This malady was defined in Quain's Standard Dictionary of Medicine as late as 1894 as "an earth-born poison, generated in soils, the energies of which are not expended in the growth and sustenance of healthy cultivated vegetation. By almost universal consent this poison is the cause of all the types of intermittent and remittent fevers, commonly called malarial, and of the degeneration of the blood and tissues resulting from long residence in places where this poison is generated."

"Malaria," the Encyclopedia continues, "has generally been said to be the product of heat, moisture and vegetable decomposition. The terms marsh miasm, and paludal fevers, long employed to distinguish the poison and the fevers to which it gives rise, mark the almost universal belief that the air of marshes alone is endowed with the power of generating them. That low, moist, and warm localities are generally noted as malarious, is indisputable. Marshes are not, as a rule, dangerous when abundantly covered with water; it is when the water level is lowered, and the saturated soil is exposed to the drying influence of a high temperature and the direct rays of the sun, that this poison is evolved in abundance. The production of malaria on a great scale in this way was seen in the district of Burdwan, in Bengal. The soil is alluvial, but dry; and until within the last few years, Burdwan was more salubrius than the central or eastern districts of the lower Gangetic delta. The drainage of the district became obstructed by the silting up of its natural and artificial outlets, the result being a water-logged condition of the soil, the development of malaria, and an alarming increase in the death-rate.

"Malaria is, however, generated under conditions apparently widely different from the above. When the British Army under Wellington was operating in Estremadura, the country was so arid and dry for want of rain, that the rivers and small streams were reduced to mere lines of widely detached pools; yet it was assailed by a remittent fever of such a destructive malignity that, says Ferguson, who records the fact, 'the enemy and all Europe believed that the British host was extirpated.'"

Again "The disturbance of soil that has long been fallow is often followed, both in hot and temperate climates, by the evolution of malaria. A familiar example was the prevalence of intermittent fever in Paris during the fortifications of the same city, in the reign of Louis Philippe, and on a larger scale in different parts of France when the railways were in process of construction."

It had been noted that "malaria is freely generated at the bases of mountain ranges in tropical climates," that "temperature exercises great influence over its development and activity," "many places can be visited with impunity in winter which are dangerous in summer and autumn"; that "malaria drifts along plains to a considerable distance from its source, when aided by winds sufficiently strong to propel, but not to dispel it"; that "under the influence of currents of heated air it can ascend, in dangerous concentration, far above its source"; that "a belt of forest interposed between any malarial place and human habitations affords considerable protection."

Could anything be more mysterious than this picture? Yet only three years after this article appeared in Quain's Encyclopedia the mystery was solved.

The germ of malaria, a Protozoan parasite which destroys the red cells of the blood, had been first seen by a French surgeon, Laveran, in 1880, and an individual observer here and there had suggested a possible connection between malaria and mosquitoes. In 1883 an American, A. F. A. King, had urged with special force the hypothesis that "the mosquito is the real source of the disease rather than the inhalation or cutaneous absorption of a marsh vapor."

It was only in the early nineties, however, that the proof of this assumption was at last furnished. Patrick Manson and Ronald Ross, two English physicians, at that time began serious work on the mosquito theory and in 1897 Ross discovered the germ of bird malaria in the stomach of the mosquito. The Italians, Grassi and Bignami, first demonstrated the germ of human malaria in the body of the mosquito in 1898 and in 1900 Sambon and Low showed that it was possible to remain immune from disease in the most malarious region of the Roman Campagna if protected against mosquitoes while Dr. Manson's son and another volunteer were inoculated with malaria in England by the bites of infected mosquitoes shipped alive from Italy.

The malaria germ is an example of a parasite which requires two different hosts in which to complete its life history. Asexual cycles are completed in the blood of man at regular intervals of 48 or 72 hours, the recurrent period of chill and fever corresponding to the time at which new generations are set free in the blood stream. The complete development of the parasite, however, must be accomplished in the stomach of a mosquito belonging to the genus *Anopheles*.

When one of these mosquitoes sucks the blood of a malaria patient it draws in the germ which passes through its sexual stage in the body of the mosquito; and after a period of ten or twelve days a new generation of germs find their way into the salivary glands of the mosquito, where they lie ready to infect any new victim who may be bitten by the insect.

The control of mosquito breeding, then, at last offered definite hope of checking this disease which had laid so heavy a burden upon many populous countries and some of the most fertile regions of the earth.

Celli estimated that malaria caused two million cases of disease and 15,000 deaths a year in Italy. We have no adequate statistics of its ravages in the southern United States, although the importance of the problem has recently been forcibly set forth in an admirable monograph by Mr. F. L. Hoffman.

A careful study made in Alabama in 1911 revealed 70,000 cases and 770 deaths in that one state and that one year. Certain counties in southern Missouri have experienced death rates from malaria of over 100, and in one instance nearly 300 per 100,000 population. Howard estimates the money loss due to this disease in the United States at $100,000,000 a year.

During the past summer (1917) malaria was the second largest cause of sickness among our American troops in mobilization camps.

## CONTROL OF MOSQUITO-BORNE DISEASE

The control of mosquito-borne disease involves five principal measures: (1) the elimination of mosquito-breeding places, (2) the destruction of mosquito larvæ in accumulations of water which can-

Fig. 17. MOSQUITO-BREEDING NEW JERSEY MARSHLAND BEFORE DRAINAGE

Fig. 18. SAME AREA SHOWN IN Fig. 17 AFTER DRAINAGE

not be removed, (3) the destruction of adults, (4) the protection of human beings from access of mosquitoes, and (5) immunization and treatment by the use of quinine.

Those who would control injurious insects should use a combination of common sense and knowledge of the insects' habits. It should not be necessary to mention the second factor, for common sense would point out the necessity of such knowledge, except that so many otherwise sensible people pick up a smattering of entomology and straightway feel competent to handle the complicated problems presented in nature. No important piece of work should be undertaken without expert help. On the other hand, mere knowledge of the insect's habits is not sufficient, as has been shown by some utterly impractical methods of control which have been suggested. The notes which have been given here on the habits of mosquitoes are the merest outlines and, furthermore, refer chiefly to those species which seriously trouble man.

The most fundamental of all measures of protection is the removal of the original source of all mosquito breeding, accumulations of stagnant or sluggishly moving water. The particular measures adopted must vary widely with the type of mosquito to be dealt with. Along the shores of the eastern United States, for example, the salt-marsh mosquito, *Culex sollicitans*, furnishes one of the most important problems from the standpoint of nuisance, although this species is not a carrier of disease. The salt-marsh areas and the neighboring country may be kept reasonably free from mosquitoes by the construction of comprehensive systems of drainage ditches which keep down the water level of the land adjacent and are themselves flushed out by the tide. Fresh water swamps and pools where species of *Anopheles* breed may be treated in a similar way or in some cases may more economically be filled in.

In dealing with the common malarial mosquito of the central United States, *Anopheles quadrimaculatus*, special attention must be devoted to sluggish streams clogged with vegetable growth. If such streams are straightened and cleared of weeds their rapid flow will no longer be suitable for mosquito breeding. On the other hand the *Culex pipiens* and *Aëdes calopus* are house mosquitoes, and the most important measure in checking these insects is the removal of small accumulations of stagnant water in the immediate neighborhood of habitations. Such inconspicuous breeding places may produce in the aggregate great numbers of mosquitoes; and every anti-mosquito campaign must include provision for systematic house-to-house inspection if it is to be successful.

Watch, then, for unused barrels, tubs, and buckets; roadside puddles; hoof prints, ruts, and depressions of all sorts; barn-yard pools; and the like. In cities, special attention must be paid to the catch basins of street sewers which are often prolific breeding places. In attempting to locate wrigglers in such places water should be skimmed (not scooped) from the margins of the water in a white-lined cup or dipper. Fountain-basins should contain goldfish since these fish are voracious feeders on mosquito eggs and larvæ, or the basins should be emptied and thoroughly dried at least once a week

Fig. 19. OILING A MOSQUITO-BREEDING SWAMP

during the mosquito season. If for any reason a pool or pond cannot be drained there are two principal methods of preventing it from furnishing the neighborhood with mosquitoes: the surface may be covered once a week with a film of oil; or surface-vegetation may be removed, the sides of the pool made sharp and steep, and the pool well stocked with goldfish. The first method is not entirely satisfactory since the oil must be renewed so often, and also because an oiled pool has an unpleasant look and odor. Kerosene spreads well but evaporates quickly: crude oil lasts longer but does not

spread so well and larvæ survive between the patches of oil. A mixture of about equal parts of kerosene and crude oil is rather satisfactory. It should be applied with a spray-pump. Very few, if any, of the numerous patented oils are worth the money. "Larvicide" is made from crude carbolic acid; it was used in the Panama Canal work, but water treated with it is poisonous to stock.

Of all the natural enemies of mosquitoes, fish are the most important, and of these goldfish are the most dependable and easily secured, but small ones are much better than large ones. Top minnows, such as species of *Gambusia* and *Heterandria* (*Fundulus*) are the most important natural enemies of mosquitoes. It is true that numerous aquatic insects feed, to some extent, on mosquito larvæ and pupæ, but they are rarely numerous enough to be of much value, and their numbers cannot easily be increased in any given pool. The usefulness of dragon-fly larvæ and adults has been greatly exaggerated. Tadpoles are vegetarians and do not make a practice of eating larvæ.

Since *Anopheles* larvæ frequently live in water which flows rapidly enough to wash away oil, and since they keep close to the surface of the water, getting above leaves of aquatic plants where fish do not see them, they are rather difficult to control. To make matters worse, they are the mosquitoes which we are particularly anxious to get rid of since they are the only ones known to carry disease in the North. Cleaning the edges of streams or ponds, clearing away aquatic vegetation, and keeping a good stock of fish seem to be the only feasible methods of control, although in small brooks a constant supply of oil may be furnished from a specially designed automatic drip can.

In regions where malaria or yellow fever or any other mosquito-borne disease prevails, such measures should be supplemented by careful exclusion of mosquitoes by the use of window screens and bed canopies, and special precautions should be taken to prevent the biting of those suffering from disease by mosquitoes which may carry the infection to others.

The application of these various methods of mosquito control, with thoroughness and over sufficient areas, has yielded results of the most definite and tangible kind. In the Italian Campagna the proportion of the population infected with malaria was reduced from 65% to 12% by measures directed toward the eradication of the *Anopheles* mosquito and was then brought down to 4% by the free distribution and vigorous advertisement of the value of prophylactic doses of quinine. Between 1902 and 1908 the deaths from malaria in the whole kingdom of Italy fell from 16,000 to 4,000.


THE ANTI - MALARIA CAMPAIGN IN ITALY
MORTALITY PER 1000 POPULATION
FROM 0.00 TO 0.01
.01 .05
.05 .10
.10 .20
.20 .40
.40 .60
.60 .80
.80 1.00
1.00 2.00
2.00 3.00
1900
1908
MORTALITY FROM MALARIA IN ITALY
MALARIA DEATHS
DEATHS
20000
15000
10000
5000
AMOUNT QUININE DISTRIBUTED
KGR
5000
10000
15000
20000
25000
30000
35000
40000
45000
QUININE IMPORTED
PRIVATE MEASURES
BY STATE
SOLD
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
MORTALITY FROM MALARIA AND CONSUMPTION OF QUININE IN ITALY

Fig. 20

## THE CONQUEST OF YELLOW FEVER

The discovery of the mosquito transmission of yellow fever is one of the most striking and dramatic chapters of sanitary science and one of the brightest episodes in the history of our country.

Between the years 1702 and 1800 this terrible disease had appeared in the United States thirty-five times and between 1800 and 1879 it visited the country every year with two exceptions. In 1793 a tenth of the population of Philadelphia are said to have perished from its ravages.

Mathew Carey writes of this epidemic, "the consternation of the people of Philadelphia at this period was carried beyond all bounds. . . . . People hastily shifted their course at the sight of a hearse coming towards them. Many never walked on the foot-path but went into the middle of the street, to avoid being infected in passing by houses wherein people had died. Acquaintances and friends avoided each other in the streets and only signified their regard by a cold nod. The old custom of shaking hands fell into such disuse that many shrunk back with affright at even the offer of the hand. A person with a crêpe, or any appearance of mourning, was shunned like a viper. And many valued themselves highly on the skill and address with which they got to the windward of every person they met. Indeed, it is not probable that London, at the last stage of the plague, exhibited stronger marks of terror than were to be seen in Philadelphia from the 24th or 25th of August till pretty late in September."

The Philadelphia epidemic was the occasion of a vigorous discussion as to the contagiousness or non-contagiousness of the disease in which the eminent Dr. Benjamin Rush was finally converted from the latter to the former view. For over a century arguments were advanced pro and con, without conclusive result, and as late as 1898 the United States Marine Hospital Service summed up the matter as follows: "While yellow fever is a communicable disease, it is not contagious in the ordinary acceptation of the term, but is spread by the infection of places and articles of bedding, clothing and furniture. . . . . One has not to contend with an organism or germ which may be taken into the body with food or drink, but with an almost inexplicable poison so insidious in its approach and entrance that no trace is left behind."

Fig. 21. WALTER REED

Fig. 22. JESSE W. LAZEAR

Fig. 23. JAMES CARROLL

Fig. 24. ARISTIDES AGRAMONTE

Two years later, early in the year 1900, a commission of army officers was appointed to study the disease in Havana as a result of a number of cases which had occurred among the American troops stationed there. The Chairman of the Commission was Dr. Walter Reed, and his associates were Dr. James Carroll, Dr. Jesse W. Lazear, and Dr. Aristides Agramonte. At the very beginning, the investigators turned their attention to the mosquito as a possible agent in the transmission of the disease. Dr. Carlos J. Finlay of Havana had suggested the mosquito theory of yellow fever very convincingly in 1881, though without experimental proof, and the discoveries of Manson and Ross and Grassi and Bignami had recently demonstrated a similar origin for malaria. Reed and his colleagues were fortunate in thus beginning almost at once with a correct hypothesis.

The lower animals do not suffer from yellow fever, so that experiments upon human subjects were essential. In the words of Dr. Kelly's life of Major Reed, "after careful consideration, the Commission reached the conclusion that the results, if positive, would be of sufficient service to humanity to justify the procedure, provided, of course, that each individual subjected to experiment was fully informed of the risks he ran, and gave his free consent. The members of the Commision, however, agreed that it was their duty to run the risk involved themselves, before submitting anyone else to it."

The first successful experiment was made with Dr. Carroll, who allowed himself to be bitten on August 27 by a mosquito which had previously bitten four yellow fever patients. Four days later he was taken sick and for three days his life hung in the balance. Both he and Private W. H. Dean, the second case produced experimentally in the same way, recovered. Dr. Lazear, however, who came down with the disease, not as a result of the experimental inoculations to which he also had submitted, but from an accidental bite, was less fortunate than his colleagues, for a week later he died, after several days of delirium with black vomit.

An experimental station, named "Camp Lazear" after this first martyred member of the party, was established in the open country; and to the lasting honor of the United States Army, volunteer subjects for the experiments from among the troops were always in excess of the demand. Private John R. Kissinger and John J.

Moran, a civilian employee, were the first to volunteer "solely in the interest of humanity and the cause of science," their only stipulation being that they should receive no pecuniary reward.

The result of the experiments carried out at Camp Lazear proved beyond peradventure that yellow fever was transmitted by the bite of a certain mosquito, *Aëdes calopus*, and in no other way, for non-immunes who lived for twenty days in a small, ill-ventilated room, in which were piled clothing and bedding, loathsome with the discharges of yellow fever patients, all escaped infection, so long as they were protected from the bites of mosquitoes.

On the memorial tablet to Lazear in the Johns Hopkins Hospital is the inscription: "With more than the courage of the soldier, he risked and lost his life to show how a fearful pestilence is communicated, and how its ravages may be prevented." The same risk was freely taken by each member of the party from major to private. The result of their devotion is indicated in two of Reed's letters to his wife, "six months ago, when we landed on this island, absolutely nothing was known concerning the propagation and

Fig. 25. CAMP LAZEAR WHERE THE SECRETS OF YELLOW FEVER WERE REVEALED

spread of yellow fever—it was all an unfathomable mystery—but today the curtain has been drawn"; and later on New Year's Eve—"only ten minutes more of the old century remain. Here have I been sitting reading that most wonderful book, 'La Roche on Yellow Fever,' written in 1853. Forty-seven years later it has been permitted to me and my assistants to lift the impenetrable veil that has surrounded the causation of this most wonderful, dreadful pest of humanity and to put it on a rational and scientific basis. I thank God that this has been accomplished during the latter days of the old century. May its cure be brought out in the early days of the new."

The practical result of this discovery was immediate and striking. In the half century or so for which we have records, yellow fever had killed an average of 750 persons a year in the City of Havana. The sanitary reforms introduced by the American army of occupation which produced good results in reducing typhoid and smallpox had been powerless against yellow fever because its cause was as yet a mystery. Following immediately on the experiments at Camp Lazear, on February 15, 1901, a campaign was begun on the new lines indicated, by screening the rooms occupied by yellow fever patients and destroying all mosquitoes in the neighborhood. As a result there were six deaths in the City of Havana during the year 1901 as against 305 in the preceding year, and although sporadic cases have been introduced from other localities, yellow fever has never again established itself in Havana. The scourge of centuries was wiped out in a single year.

## THE SUCTORIA OR FLEAS

The Suctoria or fleas are small, wingless, jumping insects which are strongly compressed sideways. They are all parasitic, when adult, on warm-blooded animals; but the footless, worm-like larvæ are not. Adults of both sexes have piercing mouth-parts and suck blood. The larvæ, however, have chewing mouth-parts and feed on more solid organic material. The larvæ live in dust and refuse on the floor or ground and pupate there, usually in thin silken cocoons.

The Dermatophilidæ, one of the principal families of Suctoria, have the segments of the thorax much shortened and constricted, but the side-plates of the metathorax extend over two or three abdominal segments; the third antennal joint has no completely separated false joints; and the fully developed female, living beneath the skin of her host during her final development, has a greatly dilated abdomen. The most familiar example is *Dermatophilus penetrans*, the "chigoe," "chique," "chigger," "jigger," or "sand-flea." The fertilized female burrows under the skin, especially about the toes, and causes a nasty ulcer. The eggs which she lays in the ulcer, or the larvæ which hatch from them, drop to the ground for further development. The female may be picked or squeezed out of the ulcer and the wound should then be carefully treated to clear away the pus. As a method of control—even if not for other reasons!—the habitations of men and domesticated animals should be cleaned to destroy the larva. This species is found in the warmer parts of America and in Africa. Members of the family Pulicidæ, on the other hand, do not have the thoracic segments much constricted and shortened but the side plates of the metathorax extend over only one abdominal segment; the third antennal joint has nine more or less distinctly separated false joints; the spines on the hind tibiæ are in pairs, are few in number, and are not in a very close-set row; and none of the species burrow under the host's skin. In the genus *Ctenocephalus* both the head and the pronotum (front section of the thorax) have stout, spine-like bristles (ctenidia); the last tarsal joint has four pairs of lateral spines and, in distinction from *Neopsylla*, the eyes are distinct. In *Ceratophyllus* the head has no ctenidia but the pronotum does; the last tarsal joint has five pairs of lateral spines. In *Pulex* and *Xenopsylla* neither the head nor the pronotum has ctenidia. The distinction between these two genera is chiefly based

on internal anatomy. *Ceratophyllus fasciatus* is the rat and plague flea of temperate regions. It feeds on rats, mice, skunks, and man. In America, it seems to be confined to California; but it also occurs abundantly in Europe. *Xenopsylla cheopis* is the tropical rat and plague flea. Although it largely confines its attentions to rats, it also, unfortunately, attacks man. The cosmopolitan human flea (*Pulex irritans*) is most abundant in warm regions, and attacks rats, skunks, and domestic animals as well as its normal prey, man. The cat and dog fleas, *Ctenocephalus canis* (female's head less than twice as long as high) respectively, are common parasites.

Fig. 26. MODEL OF THE FLEA (*Pulex irritans*)
American Museum of Natural History

## THE BLACK DEATH AND ITS CONTROL

Of all the insect-borne diseases, the one that has proved in the past most deadly to mankind is bubonic plague, a malady closely bound up with the activities of the insect pests which have just been discussed. We have records of the ravages of this disease from very early times. The countries of the Levant have been centers of plague infection for 3,000 years as a result of their unique position as gateways between the East and the West. Plague among the Philistines is described in the First Book of Samuel, the golden images of tumors and of mice, prepared as sacrificial offerings, referring clearly to one of the characteristic symptoms of the disease and to its prevalence among rodents.

Fig. 27. THE PLAGUE AT EPIRUS. P. MIGNARD (1610-1695)

The first fully recorded pandemic of plague broke out at Pelusium in Egypt in 542 A. D. and spread by way of the principal trade routes of the time into Palestine and then to the rest of the known world. Procopius says of this outbreak, of which he was a witness "It spared neither island nor cave nor mountain top where man dwelt. . . . Many houses were left empty and it came to pass that many from want of relatives and servants lay unburied for several days."

The second pandemic of plague, the Black Death of the Middle Ages, originated in Mesopotamia about the middle of the eleventh century. In the track of travel and commerce, particularly on the route of the returning crusaders, it quickly spread to the West and North. It is said that 25,000,000 people, one fourth of the population of Europe, perished of plague during the fourteenth century.

A third pandemic of plague which is still going on at the present time (1918) broke out at Yunnan Fu in China in 1871 and attracted general notice when it reached Hongkong in 1894. From this point

Fig. 28. MODEL OF CORNER OF RAT-INFESTED DWELLING
American Museum of Natural History

the disease made its way to India where it raged unchecked for ten years and carried off 6,000,000 people. This time, however, the world invasion of the Black Death was to be met by a new defensive mechanism, the organized force of scientific research. A Japanese bacteriologist, Yersin, discovered the bacillus of plague in 1894 and it was soon proved that the disease from which rats were simultaneously suffering (as they had done in the days of Samuel) was the same as the human plague. The infection may be more or less chronic among the rodents, persisting among them for years as

tuberculosis infection does in man. At certain times and under certain conditions, the disease becomes more virulent, the rats die in great numbers, and infection spreads to human beings. The agent of transmission of the germ from rat to man and from man to man remained to be solved; and in 1897 and succeeding years evidence accumulated by a number of French, English, and Russian investigators began to point more and more strongly toward the flea

Fig. 29. HABITAT GROUP OF CALIFORNIA GROUND SQUIRRELS
(*Citellus variegatus beecheyi*)
American Museum of Natural History

as the intermediate carrier of the germ. Finally the experiments of the Indian Plague Commission rendered this practically certain, for they showed that infection did not spread from a sick to a well rat even when in intimate contact if fleas were absent, while if they were present, the exposed animals quickly came down with the disease. In man it is now known that plague may at times (as in Manchuria) develop a peculiar "pneumonic" type in which the

germs are discharged from the mouth and nose as in the case of a common cold. Pneumonic plague, therefore, spreads directly from man to man by contact, but in the ordinary or "bubonic" plague the germs are not discharged in any of the excretions of the body and can only be transmitted by the flea. In northern Asia the rodent host of the plague bacillus is the Siberian marmot or tarbagan, *Arctomys bobac*, and the first human victims in Manchuria were trappers and dealers in marmot skins. In California, the ground squirrel, *Citellus variegatus beecheyi*, is infected, and the United States Public Health Service up to September, 1913, had isolated plague bacilli from 1891 different individuals. A number of human

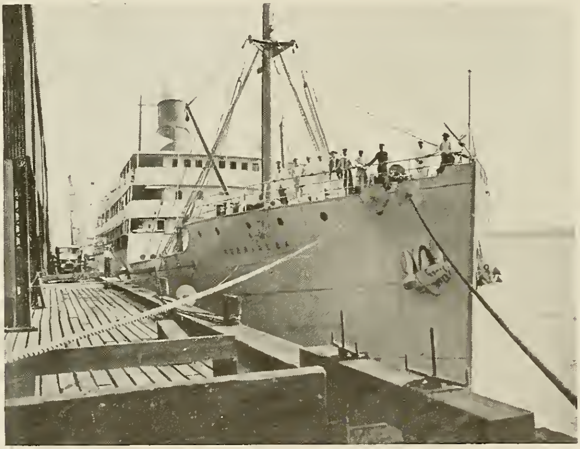

Fig. 30. SHIP EQUIPPED WITH GUARDS ON THE HAWSERS TO PREVENT LANDING OF INFECTED RATS

cases in California were traced to infection from these animals. The most important carriers of plague germs, however, are the various rats, the black rat (*Mus rattus*), the common rat of the middle ages in Europe, the brown rat (*M. norvegicus*), which has now generally supplanted the smaller and less ferocious black rat, and the roof rat (*M. alexandrinus*) which has established itself at many seaports.

The modern campaign against plague depends mainly upon the control of the rodent host. Human cases must of course be isolated but the great essential is that possibly infected rats on incoming ships should be excluded from the wharves by rat-guards on the hawsers, and rats on board destroyed by fumigation. In seaports, or other

cities where plague infection is likely to enter, comprehensive campaigns must be organized for the removal of breeding and harborage places of rats by cleaning up rubbish, for the starving out of rats by covering garbage and eliminating other accumulations of food, for trapping and shooting and poisoning rats, and for excluding rats from buildings by various forms of ratproof construction. The natural enemies of the rat,—cats, dogs, and ferrets, skunks, foxes, coyotes, weasels, minks, hawks, owls, snakes, and alligators—are often of great assistance in this campaign.

Fig. 31. THE SECOND PANDEMIC OF PLAGUE.
EXTENSION OF THE DISEASE BETWEEN 1200 AND 1450 A. D.

These methods of rat suppression have been widely successful in their application to the control of bubonic plague. The early history of the present pandemic of plague is precisely like that of the one which began in the eleventh century. It started in China, spread to Manchuria in one direction, and killed its six millions in India. Thence, following the trade routes as of old, plague infection has been carried to seaports all over the world. It has

passed east to Melbourne, Brisbane, and other Australian cities, north to Portugal and Scotland, and around the world to Brazil, Porto Rico, California, and New Orleans. We are actually to-day in the midst of a potential world pandemic of plague like that of the Middle Ages; but our knowledge of the relation of the rat to this disease has made it easy to prevent general spread in any of the countries into which infection has been introduced outside of Asia.

Fig. 32. THE THIRD PANDEMIC OF PLAGUE.
EXTENSION OF THE DISEASE BETWEEN 1897-1917.

Fig. 33. MODEL OF THE BODY LOUSE (*Pediculus vestimenti*)
American Museum of Natural History

## LICE AND BED-BUGS

Another group of insects, of great importance in connection with disease, is the family of Siphinculata known as sucking lice or Pediculidæ. They are small, more or less flattened, wingless parasites which have an unjointed, fleshy beak barely reaching the thorax. The five-jointed antennæ are short; the tarsi are single-jointed, forming a claw at the end of the tibiæ; the eyes are well developed, convex, and distinctly pigmented. The eggs, "nits," are fastened on the hair or clothing of their host. The metamorphosis is slight so that the newly hatched young closely resemble the adults, and there is no resting, pupal stage. Three or four weeks is usually sufficient time for these creatures to reach maturity from the time the egg is laid. The head-louse, *Pediculus capitis,* is more common

on the children of cleanly families than is generally admitted and it is almost the rule among the less cleanly, The former get it from the latter by contact, by using the same comb or brush, by hanging the hat on the same rack in school and in other ways. The body-louse or gray-back, *Pediculus vestimenti* (or *corporis*) is common where men gather in numbers without having, or using, adequate facilities for cleanliness. Cleanliness, in this case, refers very largely to the clothing, as this species lays its eggs on the clothes next to the skin and the lice themselves spend much of the time there. The crab-louse, *Phthirius inguinalis*, is an easily recognized species, the common name being appropriate. It infests the pubic regions and the armpits of man. Transmission sometimes occurs by way of public toilets.

The use of a fine-toothed comb dipped in kerosene is an effective remedy for the head-louse. The treatment should be repeated twice at intervals of a week. For body-lice, the clothing should be boiled, steamed, fumigated, or soaked in gasolene or benzine. The irritation caused by the lice may be relieved by a lotion of one half ounce of borax to a pint of water. In dealing with these lice when there is danger of typhus fever, the greatest care must be exercised to prevent their spread. The face and the head should be shaved and the hair burned. A liberal use of kerosene on floors and about beds is recommended. The crab-louse may be treated in the same way as the head-louse but mercurial or "blue" ointment is often used. The salve should not be strongly rubbed in or used directly after a warm bath. Vinegar makes the eggs of the lice more susceptible to treatment.

The Bed-bug, *Cimex lectularius*, an insect belonging to the Hemiptera, has received many more or less descriptive names in addition to that of "bed-bug." Some of them are "wall-louse," "red-coat," "mahogany flat," "chinch," and just "bug." Most people are familiar with this insect, whether they admit it or not; others usually recognize it, by instinct or by its reputation, the first time they meet it. There is a mistaken idea that the flat, dark-colored insects to be found under the bark of decaying logs, and the ones that occur in the nests of swallows, belong to the species under discussion. Another mistaken notion is that these creatures may become "grandfathers in a night." The eggs, which are white and oval in outline with a rim around the free end and sculpturing over

the shell, are laid in cracks and crevices in beds and in bedrooms. These eggs hatch in about a week. The young resemble the adults, except in size, and there is no pupal stage. After molting five times, the adult stage is reached; this growth takes a month or more, depending on temperature conditions and the amount of available food—the blood of man, and, if necessary, of other warm-blooded animals such as mice and poultry. Bed-bugs have been kept alive and active for a year in a tight box without any food at all. Kerosene, gasolene and benzine are effective remedies, if forced into the crevices where the bugs hide by day. The treatment should be repeated at intervals of about a week, since the eggs often withstand this treatment. For killing them on a large scale, there is nothing better than fumigation with hydrocyanic acid gas, but this is a deadly poison for man as well and should be used with caution. Those desirous of trying it should write to their State Entomologist or to the Bureau of Entomology, United States Department of Agriculture, for detailed instructions.

The bed-bug has a few natural enemies; these enemies are, however, not greatly to be preferred to the bed-bug itself. "Kissing bug," of much newspaper fame a few years ago, is a name applied to several insects which prey upon the better known pest. The "masked bed-bug hunter," *Reduvius personatus*, is one of these. The "big bed-bug" of the South, *Triantoma* (=*Conorhinus*) *sanguisuga*, is much more given to sucking human blood. "It is about an inch long; black, marked with red on the sides of the prothorax, at the base and apex of the front wings, and at the sides of the abdomen; the head is long, narrow, cylindrical, and thickest behind the eyes. It is said that the effects of its bite may last for nearly a year, and it is probable that attacks which are attributed to spiders are really the work of this insect. Out-of-doors, it feeds on insects, including grasshoppers and potato beetles" (Lutz, "Field Book of Insects").

## TYPHUS FEVER AND OTHER DISEASES CARRIED BY THE LOUSE

Typhus fever, known also as ship fever, camp fever, and jail fever, was one of the deadliest of the diseases of the Middle Ages. Wherever men were crowded together under the filthy conditions which surrounded our ancestors, this pestilence raged. In sinister alliance with famine, it scourged unhappy Ireland so persistently that it was known as "Irish ague." In England its contagion was spread even through the law-courts, and several notable outbreaks among judges, lawyers, and spectators were dubbed the "Black Assizes" during the sixteenth century. In Tuscany, between 1550 and 1554, more than a million people are said to have died of typhus.

Professor Curschmann says of this malady, "between 1846 and 1848 more than a million cases of typhus occurred in England and more than 300,000 in Ireland, the outbreak starting after the great famine of the earlier year. In every century typhus fever has followed in the wake of armies. During the Thirty Years' War it claimed more victims than did the weapons of the contestants. It was the terror of the Napoleonic campaigns and decimated the French Army, already demoralized physically and morally by the terrible retreat from Moscow. During the Crimean War it decimated both the French and English armies, especially the former."

Dr. R. Bruce Low describes the experience of France with "camp fever" as follows: "When the French in 1812 began their historical retreat from Moscow, they had at least a thousand fever cases among them, and by the time they reached Vilna many other attacks had occurred with numerous deaths. At the beginning of December, 1812, the Russians had taken 30,000 French prisoners, many of whom were ill of fever. The hospitals at Vilna were overflowing with the sick, who suffered greatly from cold and lack of food. Many had no bed or bedding, and had to lie on rotten straw, sometimes side by side with the dead. Of 25,000 cases sent to hospitals at Vilna, less than 3,000 were alive at the end of January, 1813. From the troops the disease in many instances spread to the civil population. For example, in the fortified town of Metz no fewer than 7,752 soldiers of the garrison died of typhus during 1814, as well as 1,294 other persons in the civil hospitals. From Metz the infection spread to the neighboring districts, and by the end of the year no fewer than 10,329 deaths from typhus had occurred in the

Department of the Moselle. In the years following the Napoleonic wars the disease broke out from time to time in different parts of the country, and showed special incidence among the inmates of convict prisons and local jails. In 1848 an outbreak of typhus was started by a prisoner at Amiens, who infected the judge, the clerk of the court, as well as several gendarmes and prisoners. Similar outbreaks occurred at Rheims, Toulon and elsewhere in connection with civilian prisoners.

"The next importation of typhus fever to France on a large scale by troops occurred on the return of the French military forces from the Crimea, where they had suffered severely from the disease. It is reported that out of an effective force of 120,000 men at least 12,000 were attacked by typhus during the campaign, and that half that number died.

"Following upon the return of the troops, outbreaks of typhus occurred at Marseilles, Toulon, Avignon, Paris and elsewhere."

Gradually and without any intelligently directed effort to control its spread, but apparently as a by-product of the generally improved sanitary conditions of living, typhus fever almost disappeared from civilized countries. "Typhoid" fever, named from its resemblance to the more deadly typhus, with which it was once confused, remains a serious menace, but typhus was almost forgotten in western Europe until war broke out in 1914. The table below from Doctor Bruce Low shows how the deaths from this disease have decreased in England and Wales and in Ireland.

DEATHS FROM TYPHUS FEVER IN

| | England and Wales | Ireland |
|---|---|---|
| 1869-1883 | 23,702 | 11,544 |
| 1884-1898 | 2,249 | 4,703 |
| 1899-1913 | 390 | 1,043 |

In certain parts of the world, however, where sanitary conditions remain primitive, typhus has held its own. It has occasionally found its way into central Europe from Poland and Galicia. In many districts of Mexico it has long been a serious scourge; and an infection, known as Brill's disease, which occurs in New York City, has been shown to be a mild form of typhus.

Many of the characteristics of typhus fever pointed to the probability of an insect carrier, and suspicion was finally fastened upon the louse as the most probable culprit. The coincidence between

the seasonal and geographical distribution of the disease and the insect, in particular, seemed significant, high temperature apparently being inimical to each. At last in 1909 Nicolle, Comte and Conseil succeeded in transmitting typhus fever to monkeys by the bite of the body-louse. This result was confirmed in the next year in this country by Ricketts and Wilder; and Goldberger and Anderson showed that not only the body louse (*Pediculus vestimenti*) but also the head louse (*Pediculus capitis*) may transmit the specific infection. As an illustration of the danger to which those who work on the insect-borne diseases are exposed, it may be noted that one of this group of devoted experimenters, Howard T. Ricketts, contracted the disease in the course of his investigations and died, almost at the outset of a brilliantly promising career.

With the outbreak of the European War in 1914, typhus again came into public notice as it broke out in malignant form on the eastern battle-front. Its effects upon the course of campaigns in the Balkans is said to have been very material; but the French, German and Russian armies have been protected against its ravages by elaborate provisions for the destruction of lice by the disinfection of clothing and the cleansing and disinfection of the person, particularly of the hair.

The body louse usually conceals itself in the folds of the clothing, depositing its eggs along the seams and wrinkles. A female may deposit nearly 300 eggs which hatch in 3-4 days and reach maturity in 15-18 days. According to recent studies reported in English medical journals,* lice are able to live without food for 2-6 days. They become rigid with cold at 10° F. and are killed in 2-6 hours at 104° F.

Among the various substances which have been employed for the destruction of lice, the most efficient appear to be a killing powder composed of 96 per cent. naphthalene, 2 per cent. creosote, and 2 per cent. iodoform, and an ointment known as vermijelli. The soldier's clothing and equipment may be freed from lice by treatment in either dry or moist heat sterilizers or in special sterilizers which make use of the simultaneous effect of heat and formaldehyde in vacuo. Ironing the seams of garments with a hot iron is a simple and generally effective method. Military encampments are usually provided with special stations for "delousing" or "depediculization,"

*An excellent review of recent contributions to the biology of the louse is to be found in "Household and Camp Insects" by E. P. Felt, Bull. No. 194, New York State Museum.

so arranged that while the men are being bathed their clothes are simultaneously freed from lice by one of the methods described above.

In addition to typhus, a form of relapsing fever is not uncommonly spread in Russia and in other countries of southeastern Europe by the bite of the louse, and this disease has offered one of the serious problems of army sanitation on the eastern front.

## OTHER DISEASES TRANSMITTED BY ARTHROPODS

In addition to the insect-borne diseases mentioned above, there are many other diseases of tropical countries, which are transmitted in a similar way by insects or by their relatives, the ticks. Among the most important of these are sleeping sickness and other diseases caused by the Protozoan parasites of the genus *Trypanosoma*, and transmitted by the biting flies of the genus *Glossina*, and certain forms of relapsing fevers and similar maladies, caused by spirochætal parasites transmitted by ticks.

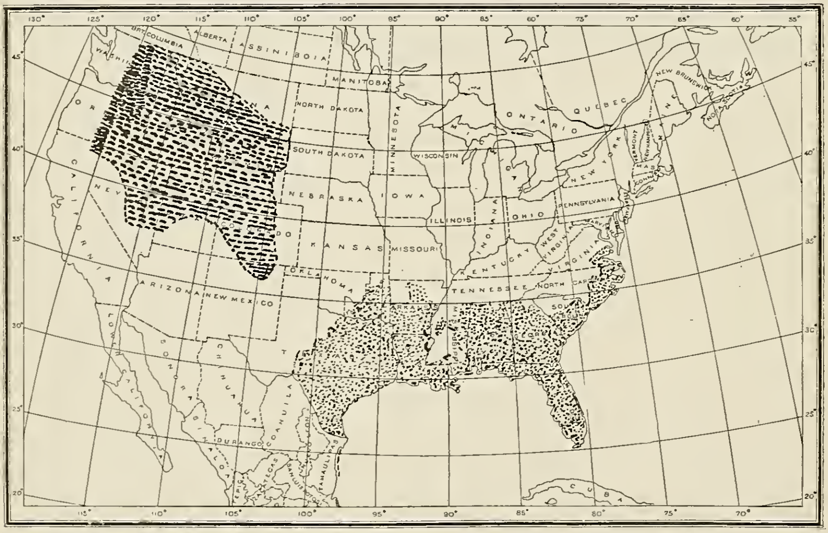


Fig. 34. DISTRIBUTION OF TEXAS FEVER OF CATTLE AND ROCKY MOUNTAIN TICK FEVER

The ticks are not insects at all but belong to the Acarina or mites (see page 4). The first of all the arthropod-borne diseases to be definitely worked out was the serious cattle plague, known in our Southwestern States as Texas fever and in Australia as redwater fever. In 1889 Smith and Kilbourne showed that the causative agent in this disease was a Protozoan parasite (*Babesia*) and that it was carried by the bite of a tick, *Boophilus annulatus*. Rocky Mountain spotted fever, which attacks visitors to the Bitterroot Valley and other areas in the Mountain States, is spread by *Dermacentor andersoni* and other ticks. The most terrible of tick-borne diseases, however, are the African tick fevers or relapsing fevers caused by different species of spirochætes.

Fig. 35. THE TSETSE FLY *(Glossina morsitans)*

Fig. 36. TYPICAL BREEDING PLACE OF GLOSSINA ON THE BELGIAN CONGO

The head- and body-lice, as has been indicated, are the agents in the transmission of typhus fever and are probably active in the spread of European relapsing fever as well, while the body-louse is believed to play a part in the transmission of the special form of relapsing fever which occurs in northern Africa. Bed-bugs (*Cimex*) and assassin-bugs (*Conorhinus*) are probably the agents in disseminating Opilaçao or Chagas fever in Brazil and Kala-azar or dum-dum fever in India and China.

Of the trypanosome diseases, the most important are the cattle disease of South Africa, Nagana, carried by *Glossina morsitans*, and the sleeping sickness of man. It is estimated that between 1900 and 1910 there were 200,000 deaths from sleeping sickness in the Uganda Protectorate alone. The particular trypanosome which causes this malady is carried by another biting fly, *Glossina palpalis*, which lives in rather sharply limited areas of dense forest and undergrowth along the shores of lakes or rivers. Clearing the jungle for a hundred yards along the water courses and for three hundred yards about all villages, screening of houses, protection of the body against bites, and the isolation of the sick are among the most important preventive measures in use against this disease. Surra, a cattle disease of Asia, Malaysia, and the Philippines, somewhat similar to Nagana, is a trypanosome disease spread by various blood-sucking flies, while sand flies (*Phlebotomus*) carry the unknown germs of the Pappatici fever of the Mediterranean and Verruga in Peru. The suspicion that epidemic anterior poliomyelitis (infant paralysis) and pellagra are causally connected with biting flies (*Stomoxys*, *Simulium*) has, on the other hand, not been substantiated.

Among the mosquitoes, besides the various species of *Anopheles*, which carry the germs of malaria, and the *Aëdes*, which transmits yellow fever, *Culex fatigans* spreads the virus of Dengue fever, and with other mosquitoes is the agent in transmitting the microscopic worms (*Filaria*) which cause elephantiasis and other forms of filariasis.

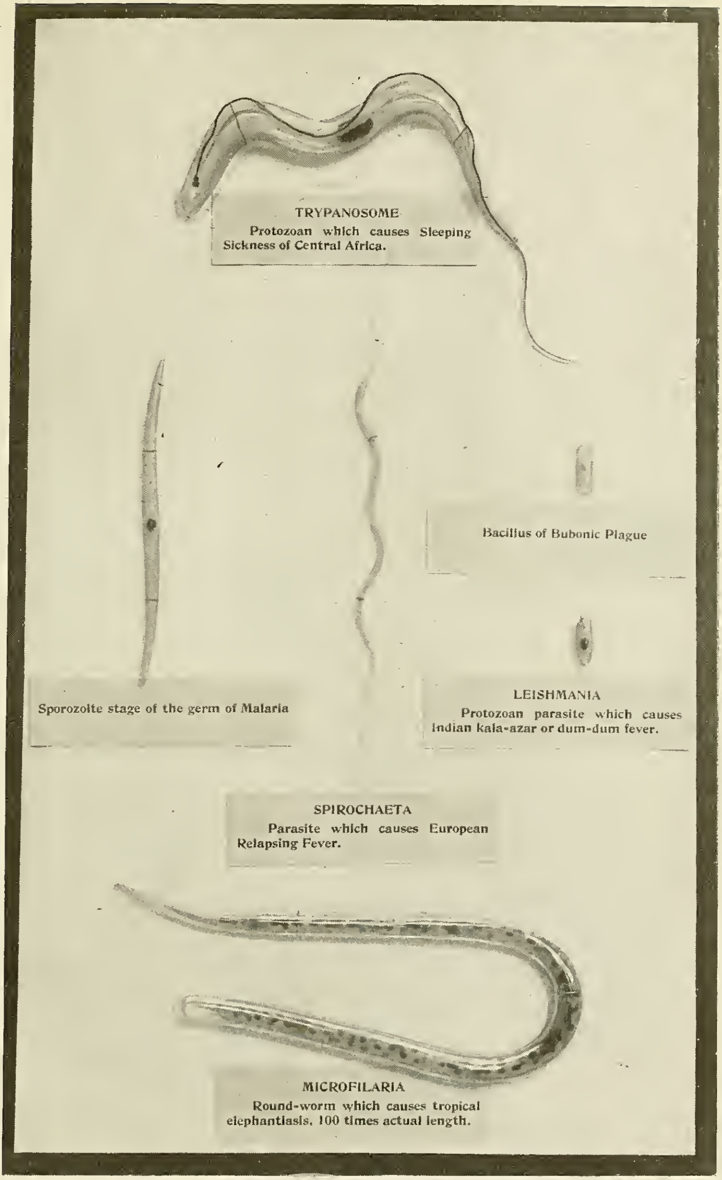


Fig. 37. MODELS OF BLOOD PARASITES
American Museum of Natural History

## Tabular Review of Principal Insect-Borne Diseases

| DISEASE | PARASITE | CARRIER |
|---|---|---|
| | | ACARINA (mites) |
| West African Tick Fever | *Spirochæta duttoni* | *Ornithodorus moubata* |
| Rocky Mountain Spotted Fever | ........................ | *Dermacentor andersoni* and other ticks |
| Opilaçao (or Chagas Fever) | *Trypanosoma cruzi* | *O. moubata*, also certain Hemiptera |
| Texas Fever of cattle | *Babesia bigeminum* | *Boophilus annulatus* |
| Spirochætosis of fowls | *Spirochæta gallinarum* | *Argas persicus* |
| | | HEMIPTERA (bugs) |
| Typhus Fever | ........................ | *Pediculus capitis*, *P. vestimenti* |
| Opilaçao (or Chagas Fever) of Brazil | *Trypanosoma cruzi* | *Conorrhinus megistus*, *Cimex lectularius*, *C. hemipterus*, also certain ticks |
| European Relapsing Fever | *Spirochæta recurrentis* | *P. capitis*, *P. vestimenti*, also, perhaps, bedbugs |
| North African Relapsing Fever | *Spirochæta berberi* | *Pediculus vestimenti* |
| Kala-Azar or Dum-Dum Fever | *Leishmania donovani* | *Conorrhinus rubrofasciatus* or *Cimex hemipterus* (?) |
| | | SIPHONAPTERA (fleas) |
| Bubonic Plague | *Bacillus pestis* | *Xenopsylla cheopis* and other fleas |
| Infantile splenic leishmaniasis | *Leishmania infantum* | *Pulex irritans* and other fleas |
| | | DIPTERA (flies) |
| Sleeping Sickness | *Trypanosoma gambiense* | *Glossina palpalis* |
| Nagana disease of cattle | *Trypanosoma brucei* | *Glossina morsitans* and other flies |
| Surra of cattle | A filterable virus | *Phlebotomus papatasii* |
| Verruga peruviana | ........................ | *Phlebotomus verrucarum* (?) |
| Typhoid, diarrheal disease of children, etc. | Various bacteria | *Musca domestica* (occasional accidental carrier) |
| | | DIPTERA (mosquitoes) |
| Malaria—tertian | *Plasmodium vivax* | *Anopheles maculipennis* and other *Anopheles* sp. |
| quartan | *P. malariæ* | |
| æstivo-autumnal | *P. falciparum* | |
| Yellow Fever | A filterable virus | *Aëdes calopus* |
| Filariasis | *Filaria bancrofti* | *Culex fatigans*, *Anopheles nigerrimus* and others |
| Dengue | A filterable virus | *Culex fatigans* |

## THE BUILDING OF THE PANAMA CANAL A TRIUMPH OVER INSECT-BORNE DISEASE

By far the most serious problem which confronted the United States Government in the attempt to cut a canal across the Isthmus of Panama was that of insect-borne disease.

The Isthmus was first visited by Columbus on his third voyage in 1498. Permanent settlements were established shortly thereafter by Balboa, and the conquest of Peru, about 1530, by Pizarro made the Isthmus a center of unique commercial importance. The size and magnificence of the city of Old Panama, the point from which Pizarro sailed forth, which Drake half a century later reconnoitred from both its land and water sides, and the stronghold, which the buccaneer Morgan captured, sacked, and practically destroyed in 1671, has been greatly exaggerated by the earlier chroniclers and by later but no less credulous historians. Yet it is certain that an enormous volume of travel and a vast quantity of gold and silver bullion passed across the Isthmus between Spain and her imperial colonies. The result of this constant influx of non-immunes in a region admirably adapted for the breeding of disease-carrying insects might have been anticipated. The Isthmus became "the foremost pest-hole" of the earth, "infamous for its fevers, and interesting only because of the variety of its malarial disorders and pestilences."

The failure of the attempt made by the French under de Lesseps to build an Isthmian Canal (1880-1888) was due to various causes but most of all, perhaps, to the ravages of insect-borne disease. Nothing was then known of the relation of mosquitoes to the transmission of malaria and yellow fever. The hospitals on the Isthmus were unscreened, and potted plants stood all about with water in their saucers, furnishing an ideal breeding-place for *Aëdes* mosquitoes. Even the legs of the beds were stood in cups of water to prevent ants from climbing them. It is no wonder that, as General Gorgas estimates, the French lost about one-third of their white working force each year from yellow fever alone.

When the United States undertook the work, the epoch-making discoveries of Reed and his associates had been established, and General Gorgas, fresh from his successful handling of the sanitation of Havana. was detailed as sanitary adviser to the Isthmian Canal Commission in 1904. It is difficult to believe to-day that the members

of the Commission were at first quite unconvinced by the Havana investigations and the practical application of their conclusions. As the non-immune population on the Isthmus increased, yellow fever became epidemic. In April, 1905, several of the higher officials were stricken, and panic and demoralization threatened. In June, 1905, the Governor and Chief Engineer of the Commission recommended that General Gorgas and other adherents of the "mosquito theory" should be recalled and "men with more practical views" appointed in their places. President Roosevelt, however, supported the sanitary officers with his accustomed vigor, and Mr. John F. Stevens, who was appointed in place of the former Chief Engineer, was in cordial sympathy with General Gorgas' plans. The work now moved forward rapidly. Mosquito breeding was reduced to a minimum by clearing away brush and undergrowth, by draining low lands, and by the use of larvicides. Houses were screened, and in particular malaria and yellow fever patients were rigorously isolated from the access of mosquitoes. Quinine was provided, and its systematic use as a prophylactic was persistently urged upon the working force.

The results of this sanitary work were as strikingly dramatic as those obtained at Havana. In 1904 and 1905 there were 35 deaths of employees from yellow fever on the Isthmus, but by the end of the latter year the situation was under control. In May, 1906, there was one case at Colon and there has not been a single case on the Isthmus since that date.

The deaths from malaria have been reduced from 233 in 1906 to 3 in 1916 with a larger working force, and the table of case rates below quoted from Hoffman's monograph is eloquent of the results achieved.

CONQUEST OF MOSQUITO BORNE DISEASE IN PANAMA

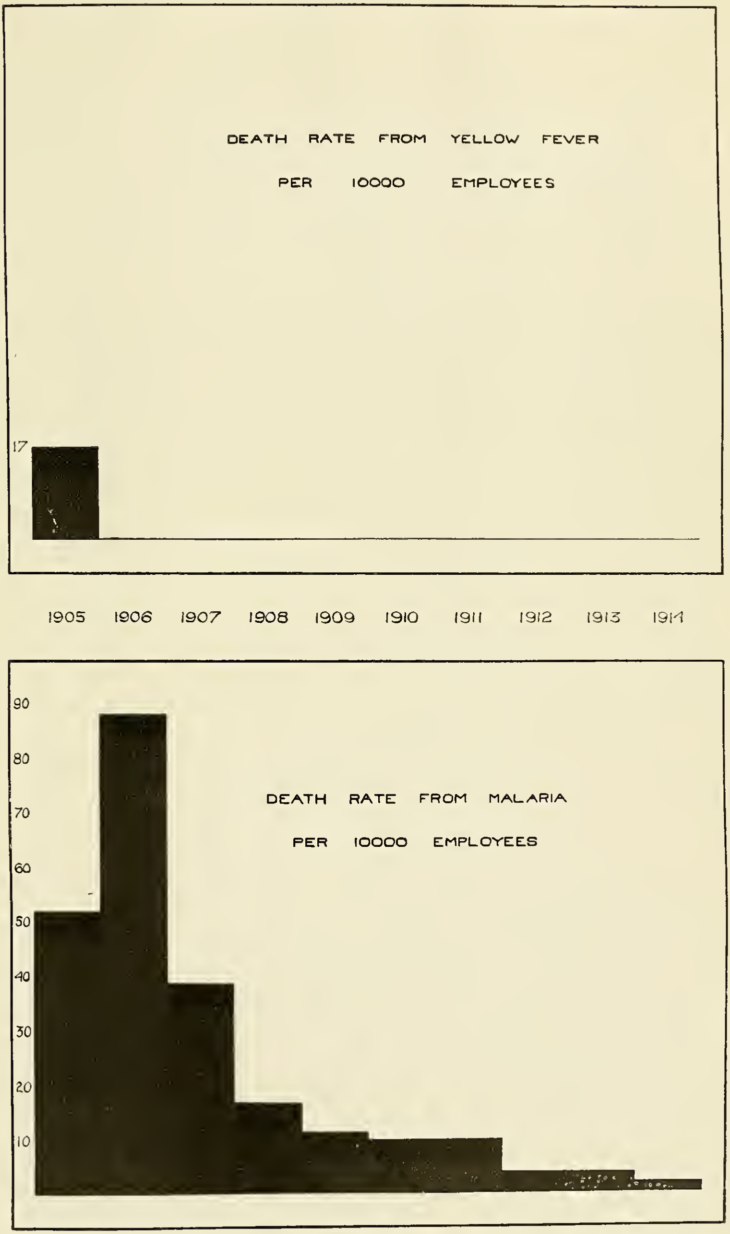


Fig. 38.

HOSPITAL CASES OF MALARIA AMONG CANAL ZONE EMPLOYEES per 100 employed

| Year | Case-rate | Year | Case-rate |
|---|---|---|---|
| 1906 | 81.9 | 1912 | 11.0 |
| 1907 | 42.6 | 1913 | 7.6 |
| 1908 | 28.2 | 1914 | 6.5 |
| 1909 | 21.6 | 1915 | 4.5 |
| 1910 | 18.7 | 1916 | 1.5 |
| 1911 | 18.4 | | |

General Gorgas estimates that, if our force of 39,000 men had suffered as the French suffered from disease, there would have been 78,000 deaths during the ten years' work on the construction of the Canal. There were actually 6,630 deaths, indicating a saving due to efficient modern sanitation of over 70,000 lives.

The late Charles Francis Adams said of this episode, in an Address before the Massachusetts Historical Society (Proceedings of the Massachusetts Historical Society for May, 1911), "the great and most startling impression left on me by what I saw on my visit to the Zone was not the magnificent ditch itself, nor the engineering feats accomplished; nor yet the construction work in progress. These are remarkable; but solely, so far as I am competent to judge, because of their magnitude and concentratedness. I have frequently seen steam shovels at work; though never so many, nor quite so busily, as now in the Culebra Cut. So I have watched pneumatic drills as they bored into the rock, and heard the detonation of the dynamite; though at Panama more drills would be working at once and in closer proximity than I ever saw before, and the blasts when the day's work was done sounded like a discharge of artillery in battle. For centuries all civilized nations have been building canals and dams, though the Gatun Dam breaks the record for bigness; the locks, too, at Panama are larger and longer, and more elaborate and imposing than any yet designed. All this is true; and yet it failed deeply to impress me. After all, it was a mere question of bigness—the something more or something less; and, as a result of organized energy and systematic coöperation of forces for rapid daily accomplishment, I still think the construction of the Pacific railroads fifty years ago at the rate of half a dozen miles a day, every material, even water, having to be hauled to the moving camp which constituted the advancing front,—

this was by far a more dramatic display than anything now to be seen on the Isthmus. Again, the Gatun Dam is a great conception; but as such the recent tunneling of the Hudson and the subterranean honeycombing of Manhattan Island, combined with the bridging of the East River, impress me more. Finally, the locks at the entrance and outlet of the proposed Chagres Lake are imposing structures; but to my mind the terminal stations built, or now in process of building, in the heart of New York City, are more imposing. As I have said, all this is a mere question of degree, and time out of mind the world has been building roads and water-ways; moreover, behind this particular water-way is the Treasury of the United States. But when it comes to the sanitation which made all that is now going on at Panama humanly and humanely possible,—vanquishing pestilence and, while harnessing the Chagres, also making it innocuous to those working and dwelling on its banks,—this is new; and the like of it the world had not before seen."

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